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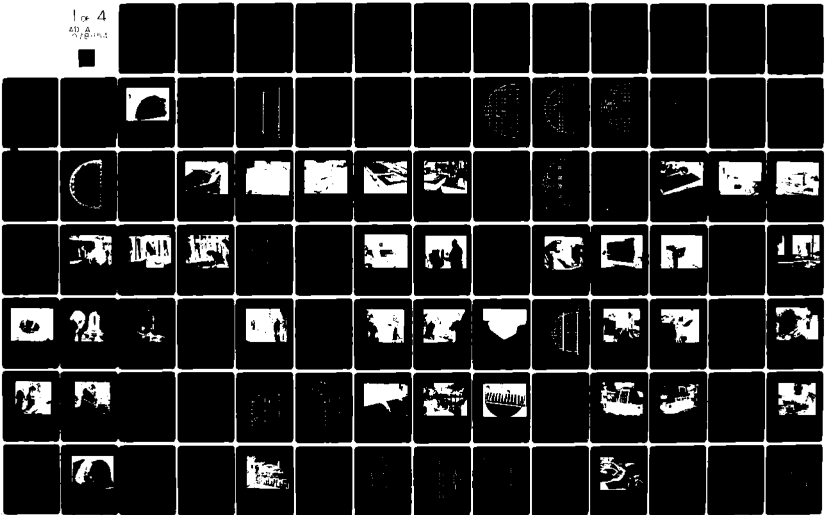

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CAST ALUMINUM STRUCTURES TECHNOLOGY (CAST)
FABRICATION OF DEMONSTRATION ARTICLES AND
PRODUCTION HARDWARE (PHASE IV)

The Boeing Company
Seattle, Washington 98124

March 1979

Technical Report AFFDL-TR-79-3029
Final Report for Period June 1977 - March 1979

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Air Force Flight Dynamics Laboratory
Air Force Wright Aeronautical Laboratories
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FOR THE COMMANDER

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The objective of CAST is to establish the necessary structural and manufacturing technologies and to demonstrate and validate the integrity, producibility, and viability of cast aluminum primary airframe structures.

This report summarizes efforts involved in the fabrication of YC-14 Station 170 Body Bulkhead castings. Fabrication phases including mold design, pattern fabrication, molding, pouring, trimming, machining and quality control are discussed.

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FOREWORD

This report was prepared by the Boeing Military Airplane Development organization of The Boeing Company, Seattle, Washington under USAF Contract F33615-76-C-3111. The contract work was performed under Project 486U under the direction of the Air Force Flight Dynamics Laboratory, Advanced Metallic Structures/Advanced Development Program Office, Wright-Patterson AFB, Ohio. A significant portion of the contract is being funded by the Metals Branch of the Manufacturing Technology Division of the Air Force Materials Laboratory. The Air Force Project Engineer is John R. Williamson of the AMS Program Office, Structural Mechanics and Dynamics Division, Air Force Flight Dynamics Laboratories (AFFDL/FBA).

The Boeing Company, Boeing Military Airplane Development organization, is the contractor, with Donald E. Strand as Program Manager and Donald D. Goehler as Technical Leader. This phase of the program was conducted by Richard G. Christner assisted by Calvin R. Belden, James W. Faber, L. Arne Logan, Robert C. McField, Howard L. Southworth, and Dean M. Kaestner of Boeing and by Timothy R. Hitchcock and Dinshaw R. Irani of Hitchcock Industries, Inc., the second-source foundry for contracted work.

The contractor's report number is D180-24610-1. This report covers work from June 1977 through March 1979. Other work performed on the CAST program is reported in:

- AFFDL-TR-77-36 - Final Report (Phase I) for period June 1976-February 1977
- AFFDL-TR-78-62 - Final Report (Phase II) for period June 1976-March 1978
- AFFDL-TR-78-7 - Final Report (Phase III) for period February 1977-December 1977

TABLE OF CONTENTS

Page

SECTION I. INTRODUCTION 1

SECTION II. PHASE IV, TASK 1--FABRICATION OF DEMONSTRATION COMPONENTS AT BOEING 3

A. MOLD DESIGN 3

1. Pouring Position and Sprue Design 3
2. Gating and Risering System 6
3. Flask Design 7
4. Cores and Core Placement 13
5. Metal Requirements 13

B. PATTERN FABRICATION 13

1. Background 13
2. Pattern Materials/Allowance 16

C. MOLD FABRICATION 16

1. Pattern Preparation 16
2. Molding 22

D. MELTING AND POURING 36

1. Metal Preparation/Pouring 36
2. Spectrographic Analysis 36
3. Degassing 40
4. Ladle Preheat 45
5. Furnace Tapping 45
6. Temperature Monitoring 47
7. Mold Pouring 47

E. MOLD SHAKEOUT/TRIMMING OPERATIONS 54

1. Mold Shakeout 54
2. Trimming 54

F. WELD CORRECTION 59

1. Defect Identification 59
2. Weld Procedure 59

Page

G. HEAT TREATMENT/STRAIGHTENING OPERATIONS 65
1. Heat Treat 65
2. Straightening Operations 65
H. MACHINING/CONVERSION COATING 68
1. Machining 68
2. Conversion Coating 68
I. CASTING WEIGHTS 68
J. FATIGUE TEST SETUP--TRANSITION STRUCTURE 70
K. QUALITY CONTROL 70
1. Description 70
2. X-Ray Inspection 72
3. Penetrant Inspection 73
4. DAS (Dendritic Arm Spacing) 79
5. Ultrasonic Inspection 81
6. Dimensional Inspection 86
7. Mechanical Properties 91
L. COST COMPARISON 91

SECTION III. PHASE IV, TASK 2--FABRICATION OF DEMONSTRATION COMPONENTS AT HITCHCOCK INDUSTRIES, INCORPORATED 97
A. INTRODUCTION 97
B. VARIATIONS IN PROCEDURES 97
1. Mold Preparation 97
2. Metal Preparation 102
3. Pouring 102
4. Mold Shakeout 102
C. QUALITY CONTROL 109
1. X-Ray Inspection 109
2. Penetrant Inspection 109
3. DAS (Dendritic Arm Spacing) 109
4. Ultrasonic Inspection 109
5. Dimensional Inspection 109
D. DISPOSITION OF CASTINGS 115

	Page
SECTION IV. CONCLUSIONS	116
REFERENCES	117
APPENDIX A. MANUFACTURING PLAN FOR YC-14 STATION 170 BULKHEAD	118
APPENDIX B. DEVELOPMENTAL TOOL ORDER, YC-14 STATION 170 BODY BULKHEAD, TRANSITION STRUCTURE	197
APPENDIX C. CAST BULKHEAD REMOVAL ORDER, FATIGUE TEST SETUP, YC-14 STATION 170 BODY BULKHEAD	237
APPENDIX D. SPECIFICATION, ALUMINUM ALLOY A357 CASTINGS, PRIMARY AIRCRAFT STRUCTURE, M-XXXX	253
APPENDIX E. SPECIFICATION, WELDING, FUSION, CORRECTION OF PRIMARY STRUCTURAL A357 ALUMINUM ALLOY CASTINGS, PROCESS FOR, W-XXXX	267
APPENDIX F. SPECIFICATION, ALUMINUM ALLOY A357 CASTINGS, DENDRITE ARM SPACING, PROCESS FOR DETERMINATION OF, D-XXXX	278

LIST OF ILLUSTRATIONS

Figure		Page
1	As-Cast YC-14 Station 170 Body Bulkhead	2
2	Gating System Layout	4
3	Cascade Sprue System	5
4	Mold Riser System--Aft Side	8
5	Mold Riser System--Forward Side	9
6	Step Gate Locations--Aft Side	10
7	Step Gate Locations--Forward Side	11
8	Mold Setup and Assembly Sequence	12
9	Core Locations--Aft Side	14
10	Core Locations--Forward Side	15
11	Body Bulkhead Pattern Buildup--Forward Side	17
12	Step Gate Fabrication--Body Bulkhead Casting Pattern	18
13	Sheet Metal Pattern Web Sections--Forward Side	19
14	Core Box Fabrication--Body Bulkhead Casting Pattern	20
15	Foward and Aft Sides of YC-14 Station 170 Body Bulkhead Pattern	21
16	Chill Locations--Aft Side	23
17	Chill Locations--Forward Side	24
18	Completed Base Flask	25
19	Ram-up Sprue Core Placement--Aft Side	26
20	Molded Flasks Ready for Stripping--Forward Side	27
21	Step Gate Pattern Stripping	29
22	Filter Screen Positioning over Step Gate Openings	30
23	Riser Sleeve Positioning over Step Gate Screens	31
24	Approximate Gagger Locations--Aft Side	32
25	Approximate Gagger Locations--Forward Side	33
26	Flask Stripping Operations	34
27	Securing a Core into an Aft Side Flask Section	35
28	Coating the Mold Cavity with Amorphous Carbon	37
29	Stacked Body Bulkhead Mold--Filling the Parting Seams	38
30	Pouring Basin Location and Mold Finishing	39
31	Taking a Molten Sample for Spectrographic Analysis	41

Figure		Page
32	Degassing Operations--Purging the Melt with Nitrogen/Chlorine...	42
33	Vacuum Freeze Chamber--Gas Check	43
34	Checking a Solidified Specimen for Trapped Gas/Oxides	44
35	Furnace Tapping	46
36	Temperature Monitoring with a Digital Immersion Pyrometer	48
37	Filling the Pouring Basin--Ready to Pull Sprue Plug	49
38	Metal Height Light Indicator Panel	50
39	Electrical Wire Locations--Aft Side	51
40	Monitoring the Metal Height Light Indicator Panel during Mold Pouring	52
41	Pouring the Bulkhead Casting	53
42	Grit Blasting Excess Sand from the Bulkhead Casting	55
43	Rough Trimming Gates and Risers from the Bulkhead Casting	56
44	Finish Grinding Excess Metal from the Bulkhead Casting	57
45	Weld Correction Locations--Bulkhead Casting M04	60
46	Weld Correction Locations--Bulkhead Casting M07	61
47	Crack Defect on a Bulkhead Casting Ready for Weld Correction	62
48	Weld Correction--Aft Side View of Bulkhead Casting	63
49	Weld Correction--Forward Side View of Bulkhead Casting	64
50	Heat Treat Fixture 162-00017 with Bulkhead Installed--Forward Side	66
51	Heat Treat Fixture 162-00017 with Bulkhead Installed--Aft Side	67
52	Machining the Bulkhead Casting in Machining Fixture 162-00018	69
53	YC-14 Station 170 Body Bulkhead Casting M07 Installed in the Transition Section Structure	71
54	Setup for Radiography of Deck Flange, WL 130	74
55	Radiographic View Locations for Bulkhead Casting M07	76
56	Radiographic and Penetrant Inspection Results--Bulkhead Casting M04	77
57	Radiographic and Penetrant Inspection Results--Bulkhead Casting M07	78
58	Polishing Steps in Metallographic Preparation of DAS Location on Full-Size Casting	80
59	Typical Cast Microstructure and Method of DAS Determination	82

Figure		Page
60	Dendritic Arm Spacing (DAS) Measurement Locations	83
61	Oscillograph Patterns of Ultrasonic Pulse-Echo Signals from Cast Materials Containing Different Levels of Porosity	85
62	Dimensional Checks on Bulkhead Casting M02	87
63	Thickness Measurements on Bulkhead Casting M02	88
64	Outer Contour Check on Bulkhead Casting M07	89
65	Random Thickness Measurements on Bulkhed Casting M07......	90
66	In-Process Dimensional Check Point Locations	92
67	Random Thickness Measurements on Bulkhead Casting M04	94
68	Hitchcock Bulkhead Casting No. 8	98
69	Overall View of CAST Program Foundry Area at Hitchcock Industries, Inc	99
70	Layout of Foundry Work Area at Hitchcock Industries, Inc.	100
71	Grooves and Vent Holes in a Corrugated Mold Segment	101
72	Torch Drying of Mold Surface and Spray Application of Pyroseal Mold Wash	103
73	Crucible in Pouring Shank	104
74	Mold and Casting being Placed in Oven for Burn-Off of Sand Binder	105
75	Casting after Removal from Bakeout Oven	106
76	Bakeout Oven after Casting was Removed, Showing Sand on Floor	107
77	Protective Skin Formed at Casting Surface by Pyroseal Mold Coating	108
78	Locations for Measurement of DAS (Dendritic Arm Spacing) on Hitchcock Bulkhead Castings	111
79	Random Thickness Measurements on Hitchcock Casting No. 2...	113
80	Random Thickness Measurements on Hitchcock Casting No. 9...	114

LIST OF TABLES

Table		Page
1	Foundry Data Summary--Boeing-Produced Bulkhead Castings	58
2	Typical X-Ray Exposures	75
3	DAS Measurements	84
4	In-Process Check Point Data for Bulkhead Casting M04	93
5	Mechanical Properties for Bulkhead Castings M04 and M07	95
6	Foundry Data Summary--Hitchcock-Produced Bulkhead Castings	110
7	DAS Measurements on Hitchcock Casting Nos. 2, 7, and 9	112

SUMMARY

A total of 20 full-scale YC-14 station 170 body/nose landing gear support bulkhead castings were fabricated in Phase IV of the Cast Aluminum Structures Technology (CAST) program. The bulkhead casting is the largest and most complex thin-wall premium-quality aluminum sand casting produced to date and the first for primary airframe structure application.

The bulkheads were cast from A357 aluminum alloy and were produced by two separate foundries in accordance with a basic manufacturing plan. The first 10 castings were fabricated by The Boeing Company foundry, Seattle, Washington. The second 10 were fabricated by Hitchcock Industries, Inc. foundry, Minneapolis, Minnesota to evaluate reproducibility of the process. The Boeing castings were assigned serial numbers M01 through M10 and the Hitchcock castings were assigned serial numbers 1 through 10.

During initial casting operations at both foundries, some problems were encountered with misruns in the wall sections and shrinkage/porosity in heavier sections. Minor adjustments in foundry techniques alleviated these problems in subsequent castings, with the result that defects remaining in the castings were either readily weld-correctable or were within acceptable levels for the intended use.

Representative castings from both foundries were subjected to dimensional inspection and nondestructive evaluation (NDE) of casting quality, including radiographic, penetrant, and ultrasonic inspection and dendritic arm spacing (DAS) measurements. Other castings were evaluated for mechanical properties, based upon test bars machined from integral coupons. Two castings from the Boeing foundry lot, serial numbers M04 and M07, were heat treated, machined, and delivered to the Air Force for full-scale structural testing at Wright-Patterson Air Force Base, Dayton, Ohio. These castings also contained weld correction areas to evaluate effects of this technique of casting repair. A complete transition section structure representing the nose section area of the YC-14 aircraft was fabricated to provide proper loading of the bulkhead during the test program.

The overall reproducibility of the bulkhead casting process from one foundry to another is well demonstrated, as revealed by a comparison of castings from the two

foundries involved in this program. Some slight differences in dimensional control and casting quality exist between the two foundries due to normal variations in detail production techniques, but, all in all, the technology transfer achieved from the process development to actual fabrication of castings in a second production foundry is excellent.

In general, the results of Phase IV work show that the casting specifications and fabrication processes developed for manufacture of the cast YC-14 station 170 body/nose landing gear support bulkhead can attain the CAST program goals and objectives. Casting properties and quality meet Engineering requirements, and it is demonstrated that production castings will satisfactorily achieve the established weight target (188 lb) and cost reduction target (30%).

SECTION I
INTRODUCTION

The purpose of the CAST program is to demonstrate that the use of premium-quality aluminum alloy castings in airframe construction can be extended to primary structural components. The program goal is to achieve this with no weight penalty and with a minimum of 30% cost savings. Specific objectives of the program are to establish necessary structural and manufacturing technologies and to demonstrate and validate improved integrity, reliability, and producibility of cast aluminum primary airframe structures. The baseline component selected to demonstrate structural casting capability is the YC-14 body/nose landing gear support bulkhead. This is the body bulkhead that provides forward support for the nose landing gear and nose gear door. A design for a sand-cast version of the bulkhead was established. The casting is 90 inches wide by 53 inches high and a major portion of the part contains web areas and channels with 0.100-inch-thick walls (Fig. 1). The finish machined casting weight is estimated to be 181 pounds, which is comparable to the fabricated sheet metal bulkhead weight.

The CAST program is a six-phase effort. The six phases include the following specific activities:

Phase I:	Preliminary Design
Phase II:	Manufacturing Methods
Phase III:	Detail Design
Phase IV:	Fabrication of Demonstration Articles and Production Hardware
Phase V:	Structural Test and Verification
Phase VI:	Technology Transfer

This report covers work conducted in Phase IV of the program. The principal objective of Phase IV is to fabricate full-scale castings of the YC-14 station 170 body/nose landing gear support bulkheads to demonstrate producibility of the process, based upon manufacturing procedures developed in preceding activities on the program. The required work was accomplished by two different qualified casting vendors, under separate tasks, as follows:

Task 1:	Fabricate 10 full-scale bulkhead castings at The Boeing Company Foundry, Seattle, Washington.
Task 2:	Fabricate 10 full-scale bulkhead castings at Hitchcock Industries, Incorporated Foundry, Minneapolis, Minnesota

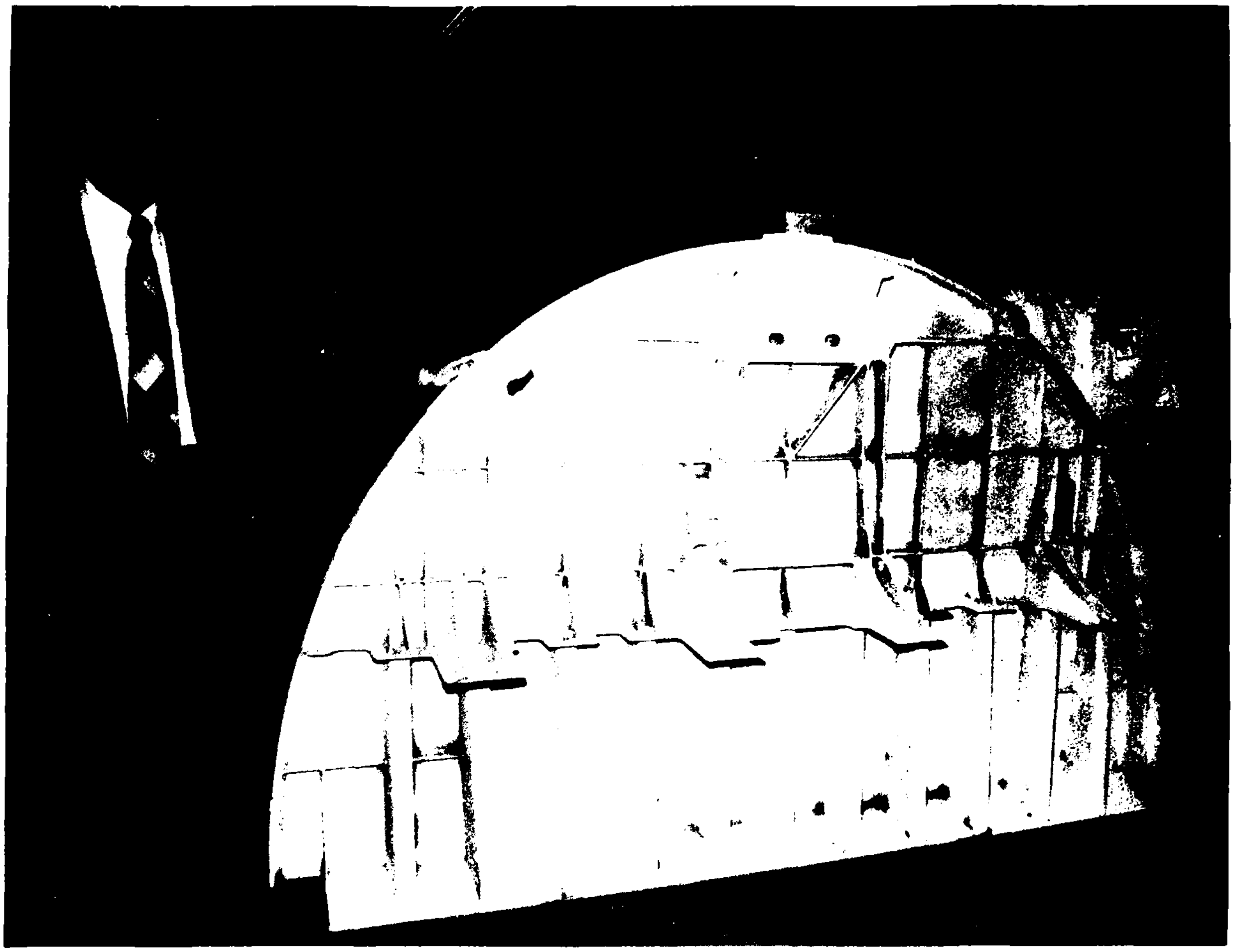


Figure 1 As Cast YC-14 Station 170 Body Bulkhead

SECTION II

PHASE IV, TASK 1—FABRICATION OF DEMONSTRATION COMPONENTS AT BOEING

A. MOLD DESIGN

1. Pouring Position and Sprue Design

Horizontal gating is the most commonly used gating technique because it is generally less complicated to mold, has less hydrostatic pressure, and produces less metal turbulence. However, large, thin-wall castings are impractical to cast in a horizontal position because of nonuniform directional solidification and the potential for mold sag.

Castings horizontally cast are usually filled from the bottom of the mold through the mold cavity and then into the risers. As a result, all metal must pass through the casting before solidification can begin. This gives rise to nonuniform directional solidification, which leads to lower mechanical properties. On the other hand, when parts are cast in the vertical position, directional solidification is promoted because metal is gated into the casting only when and where metal is required. Solidification can be controlled through judicious placement of chills. For these reasons, the vertical pouring position, shown in Figure 2, was selected.

It is generally known that large sprue heights cause metal turbulence. A cascading sprue system was designed to minimize the effect of the long vertical drop of the metal. A schematic of this system is shown in Figure 3. A series of three steps, each 24 inches in height, was used. The height of each step was controlled by the design of the mold flasks, which will be discussed later in this section. To prevent aspiration of air into the gating system, and to ensure a rapid filling of the sprue system during the initial stages of metal pouring, the total area at the base of the sprues decreased from upper to lower by approximately 50% per step. The area of the bottom sprues was 0.56 sq in., which yielded a combined metal flow rate of 20 lb/sec of metal in the runner system.

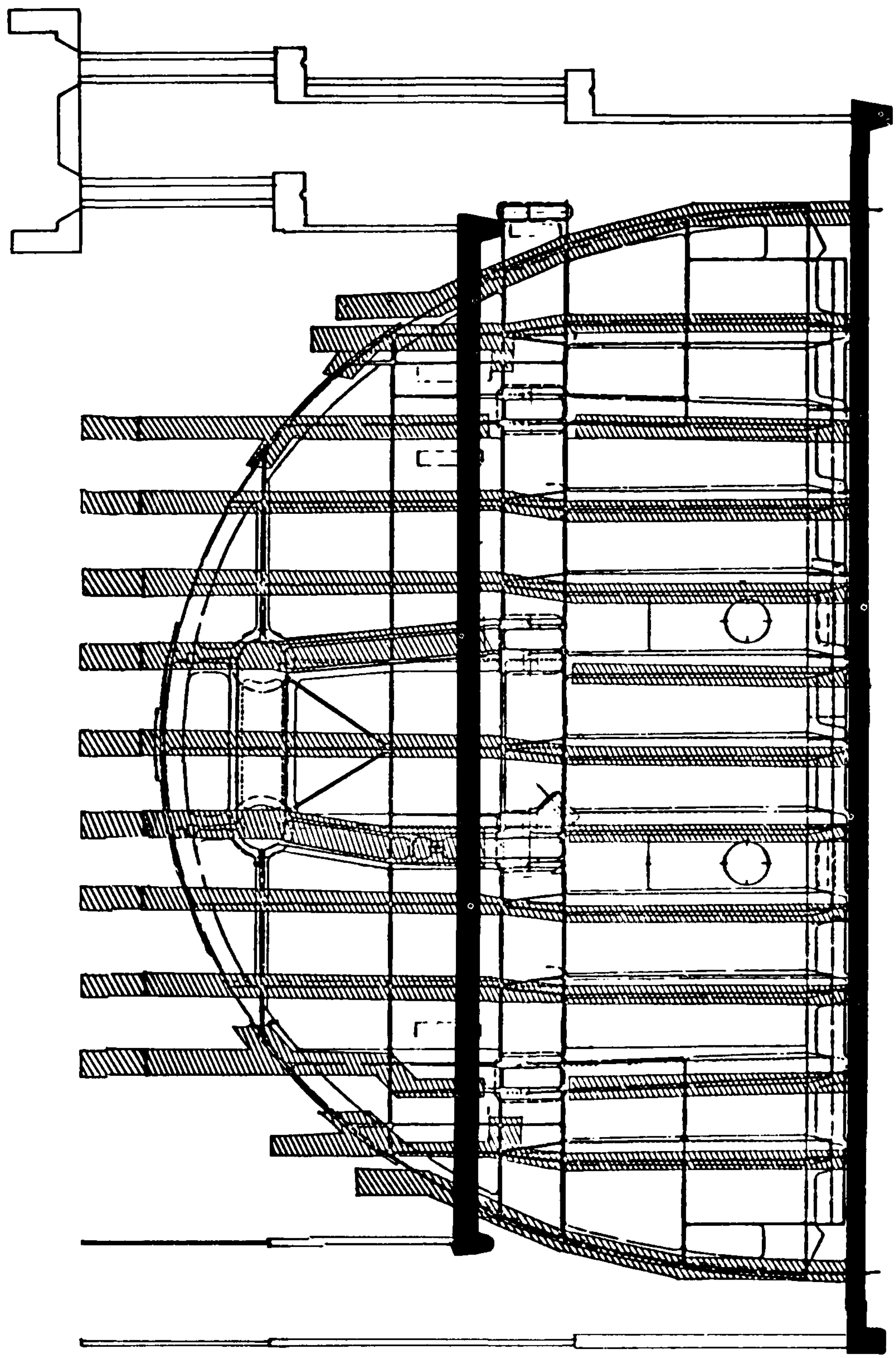


Figure 2 Gating System Layout

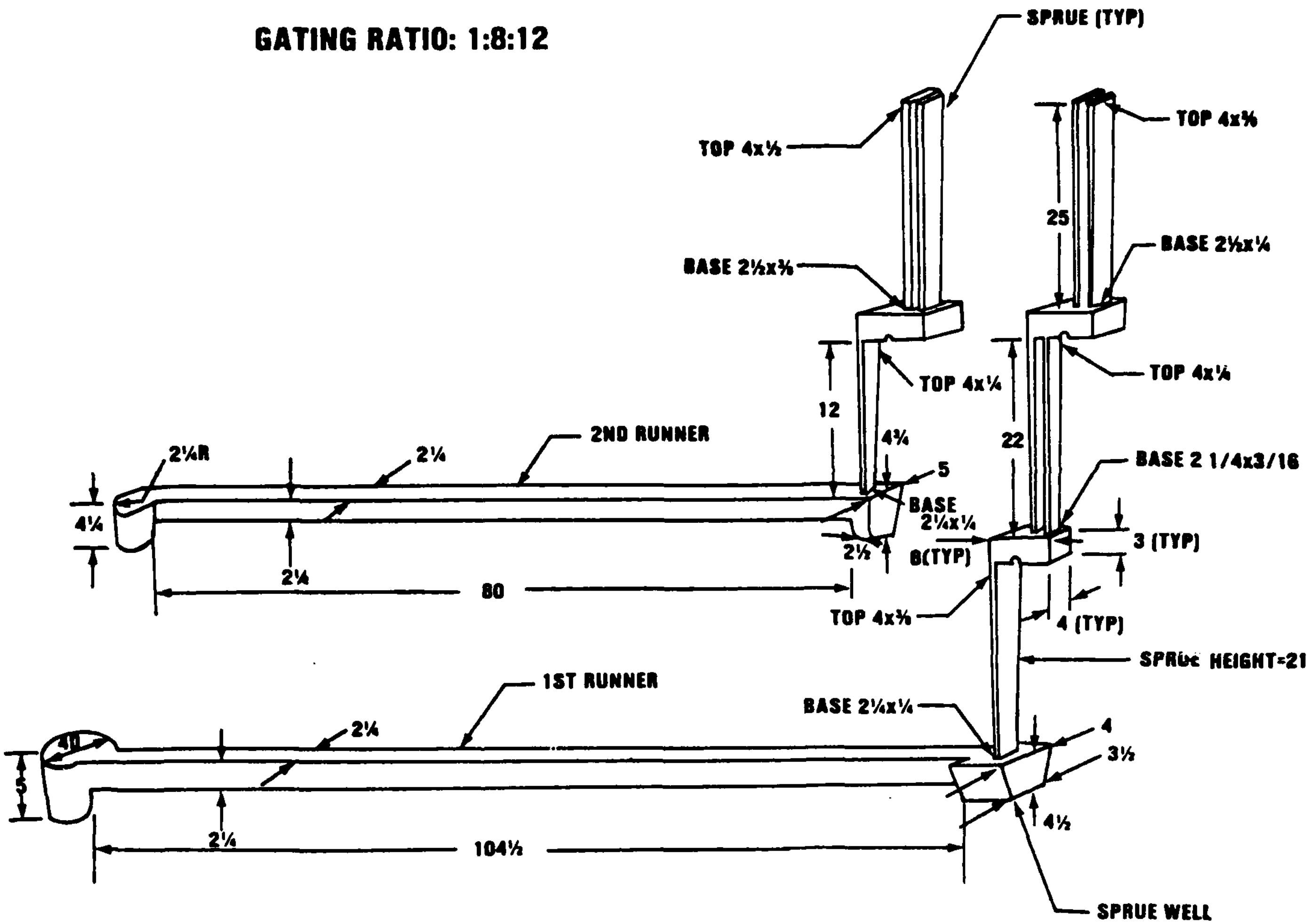


Figure 3 Cascade Sprue System

Tapered rectangular sprues, as opposed to conical sprues, were used to reduce metal swirling and minimize the formation of a vortex at the top of the sprue. Pouring basins were used to provide a consistent pouring process. A basin was placed on top of the mold, over each of the two down-sprue systems. Each basin had two openings to accommodate the two runners at the base of the down-sprue systems. Bonded sand plugs were used to stop the flow of metal into the sprues. When the level of the metal in the pouring basin reached a predetermined height, the plugs were removed and the level was maintained throughout the pour. Each basin held 100 pounds of metal, which was the amount necessary to fill the down-sprue system for the first runner.

As shown in Figure 2, the part was poured in the "upside-down" position relative to its installation position in the airplane. The reason for this choice was threefold. First, the upper portion (slanted beam) of the part required coring. These cores would have been suspended from the mold, causing a potentially serious dimensional problem if they shifted. The slanted beam provided an excellent base from which to construct the mold. Second, the risers on the outboard portion of the casting would not have to go all the way to the top of the mold, thus decreasing the amount of metal required to fill the casting. Third, the upper portion of the casting was 0.100-inch-thick wall. The probability of filling this thin area would be the greatest with the part in the upside-down position because of hotter metal and larger effective head in this region.

2. Gating and Risering System

The casting was gated from both sides using two independent gating systems, as shown in Figure 2. Each side of the casting had two runner systems. The bottom runners filled the casting to the top of the A1/B1 flasks, at which time the second runner systems were activated to fill the remainder of the casting. This multiple runner system served a twofold purpose. First, if the casting were to be filled entirely by the lower runners, the temperature loss of the metal, by the time it reached the upper regions of the casting, would be great enough to cause misruns. In addition, the large sprue height of the lower runner would tend to increase

gas porosity and dross content of the entire casting. Second, as shown in Figure 1, shelves on the aft side of the bulkhead made it almost impossible to channel metal around while providing adequate feeding. To overcome this problem, the casting below the shelves was filled with the lower runners, and the remainder of the casting was filled with the middle runners.

The runners were 2.5 x 2.5 inches, with a pop-off at the end to prevent the first metal that entered the runners from entering the mold cavity. On each side, there were 13 in-gates that connected to the vertical risers.

The risering system used was as shown in Figure 4 for the aft side and Figure 5 for the forward side. Thirteen vertical risers were located on each side of the casting. A series of step gates in each riser allowed the metal to flow into the mold cavity. These step gates, shown in Figure 6 for the aft side and Figure 7 for the forward side, not only provided a means of getting metal into the mold cavity, but also served as reservoirs of molten metal to feed the casting.

In general, the riser size used was a 2.5-inch-diameter semicircle.

3. Flask Design

Close-tolerance molding flasks were needed to ensure the dimensional accuracy of the bulkhead casting. Design of the flask sections with respect to parting planes and stripping sequence was based upon the mold fabrication sequence shown in Figure 8. Six pattern flasks and one base flask were designed and fabricated from steel. The flasks were initially designed to accommodate sodium silicate-CO_2 bonded sand. Since this type of binder has relatively low tensile strength, massive reinforced flasks were needed to prevent break-up of the mold during stripping. However, tests conducted during Phase II, "Manufacturing Methods," indicated that improved mold properties could be obtained with air-set bonded sands. The decision to use air-set bonded sands was made after fabrication of the flasks was complete.

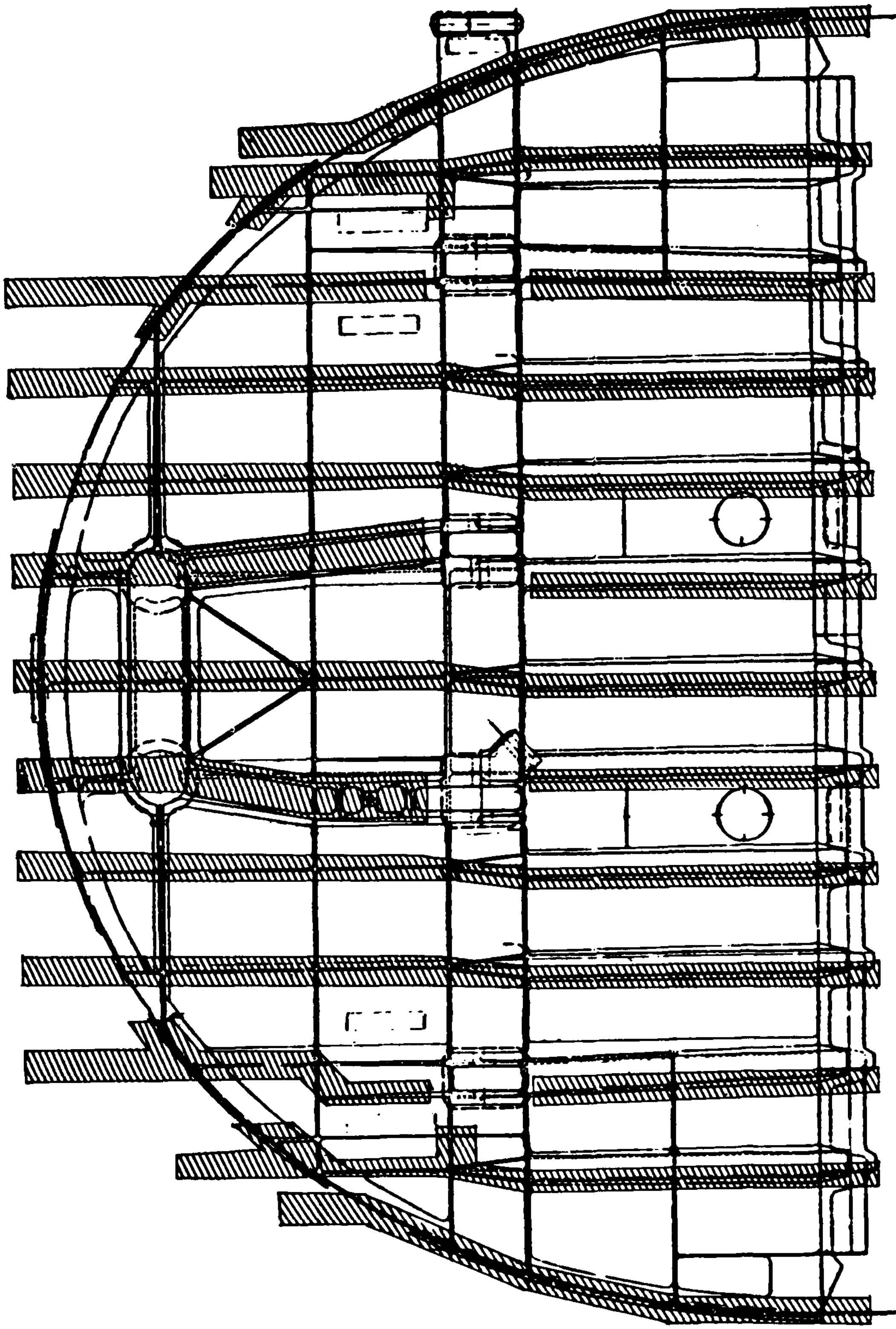


Figure 4 Mold Riser System - Aft Side

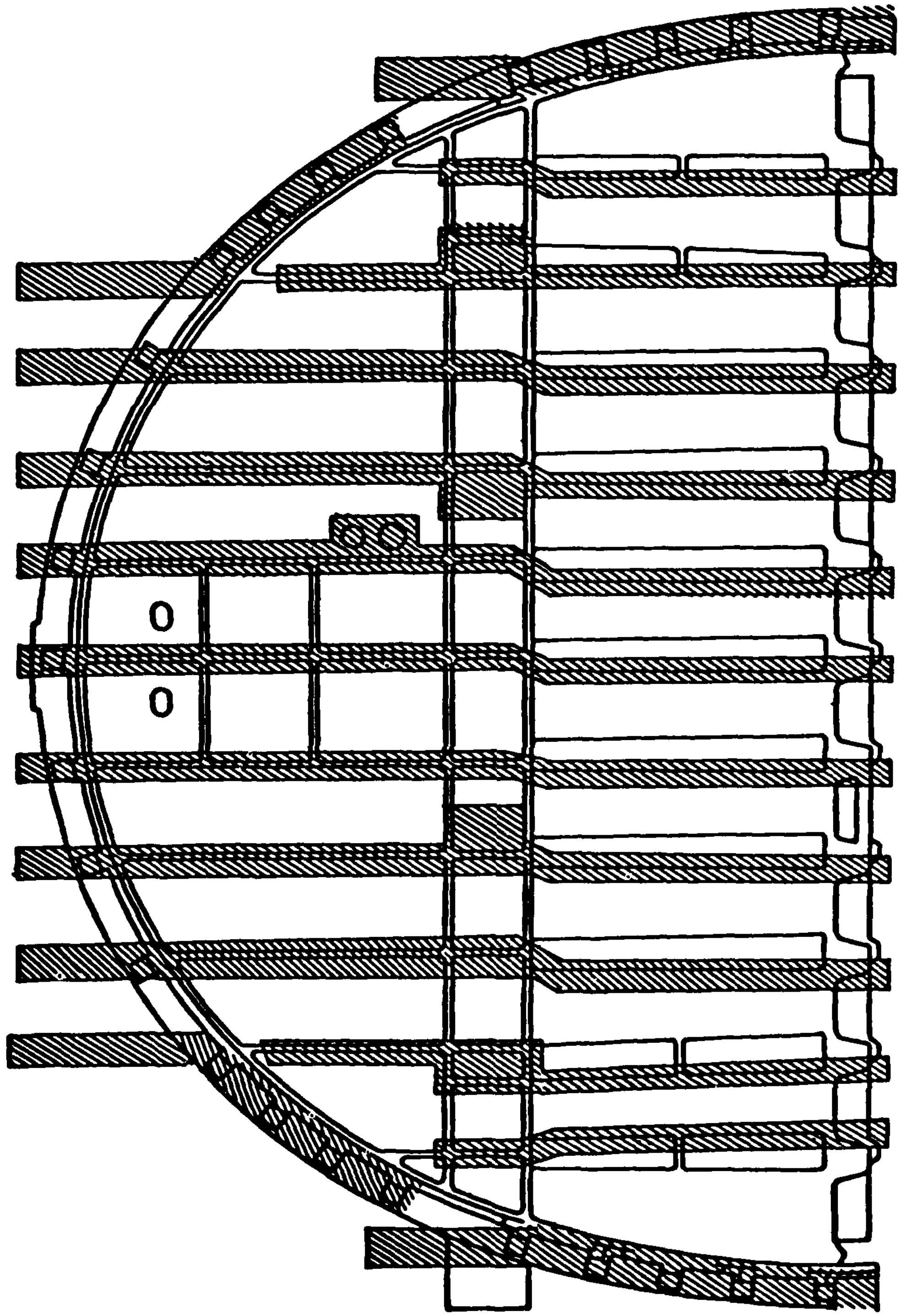


Figure 5 Mold Riser System - Forward Side

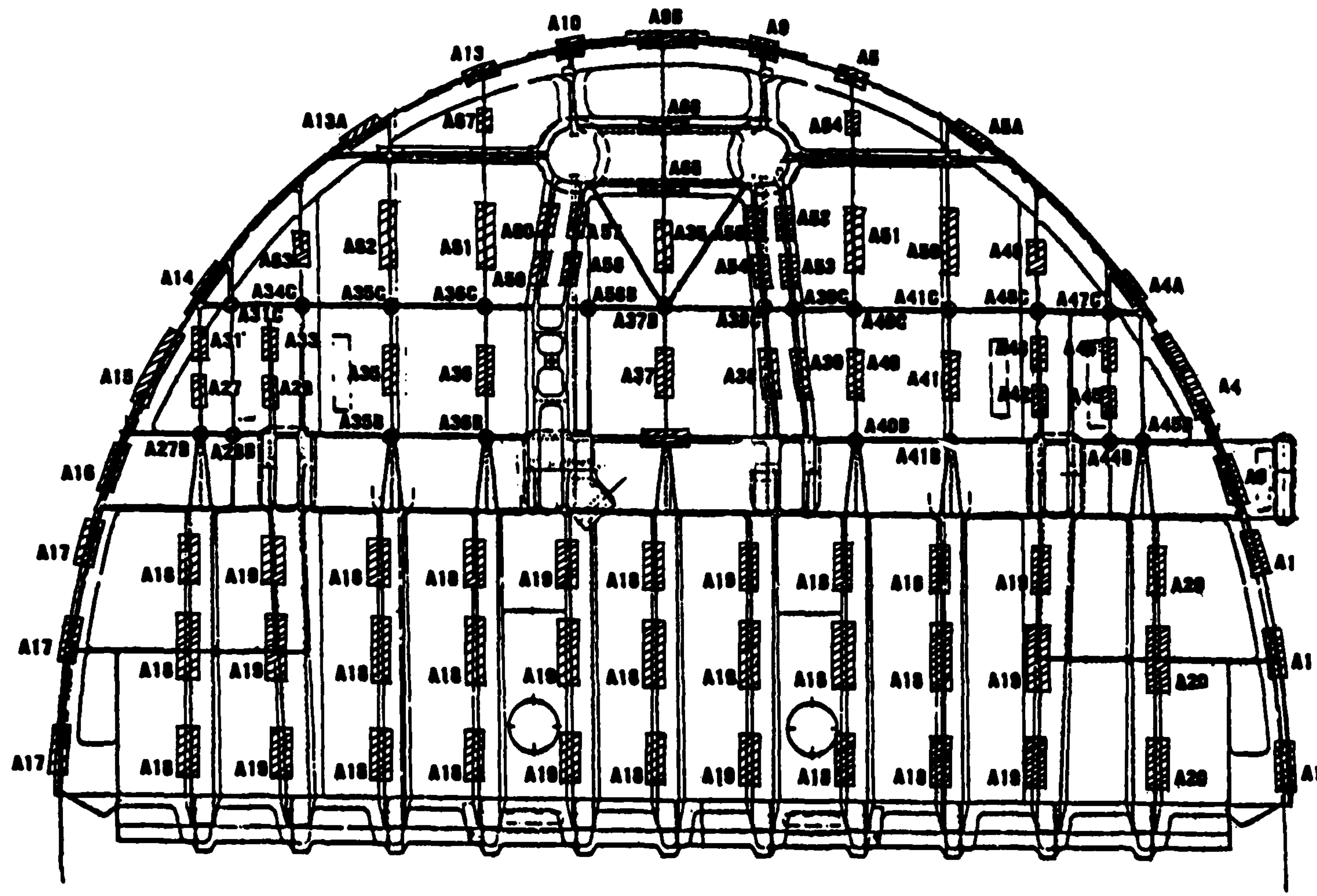


Figure 6 Step Gate Locations - Aft Side

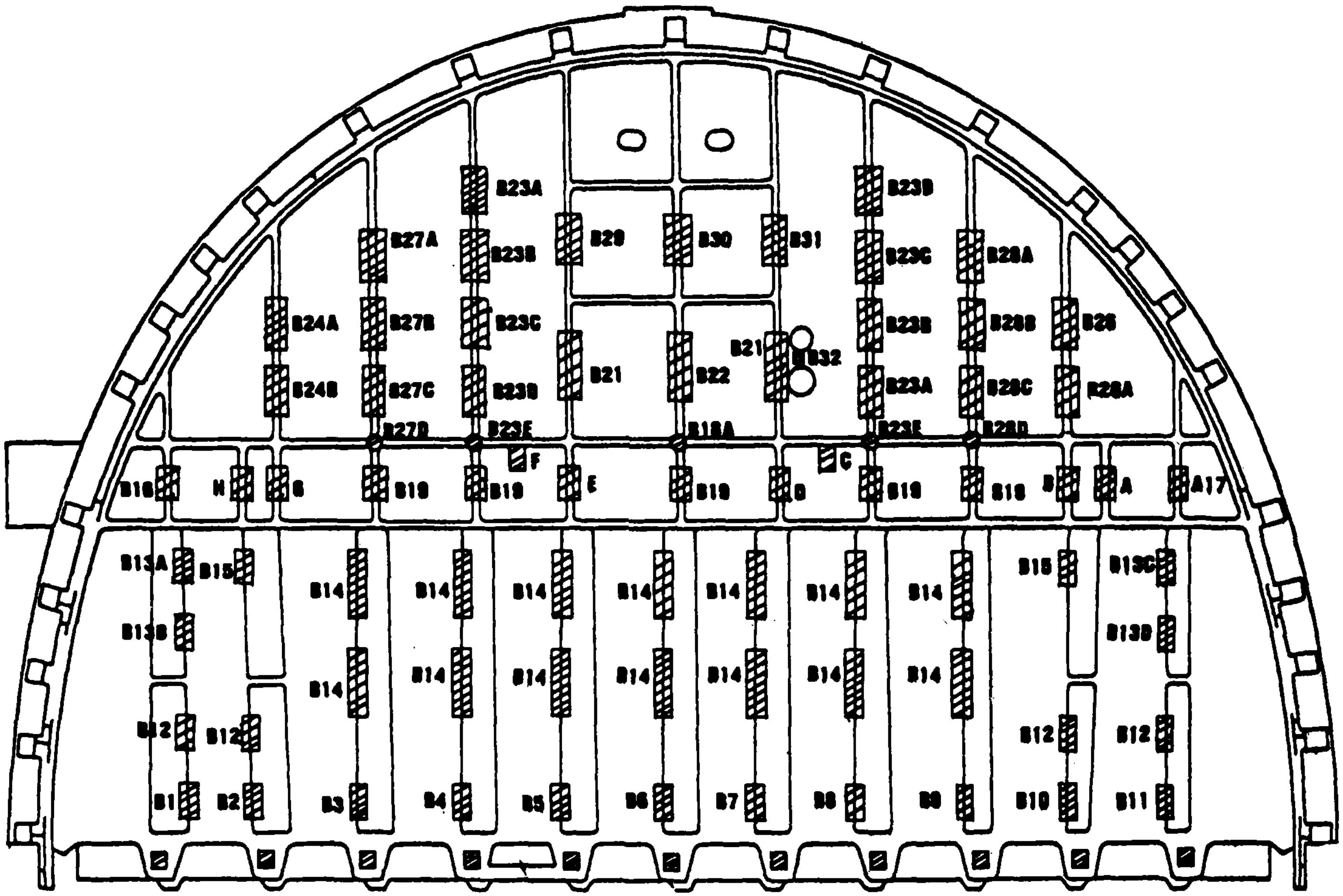


Figure 7 Step Gate Locations - Forward Side

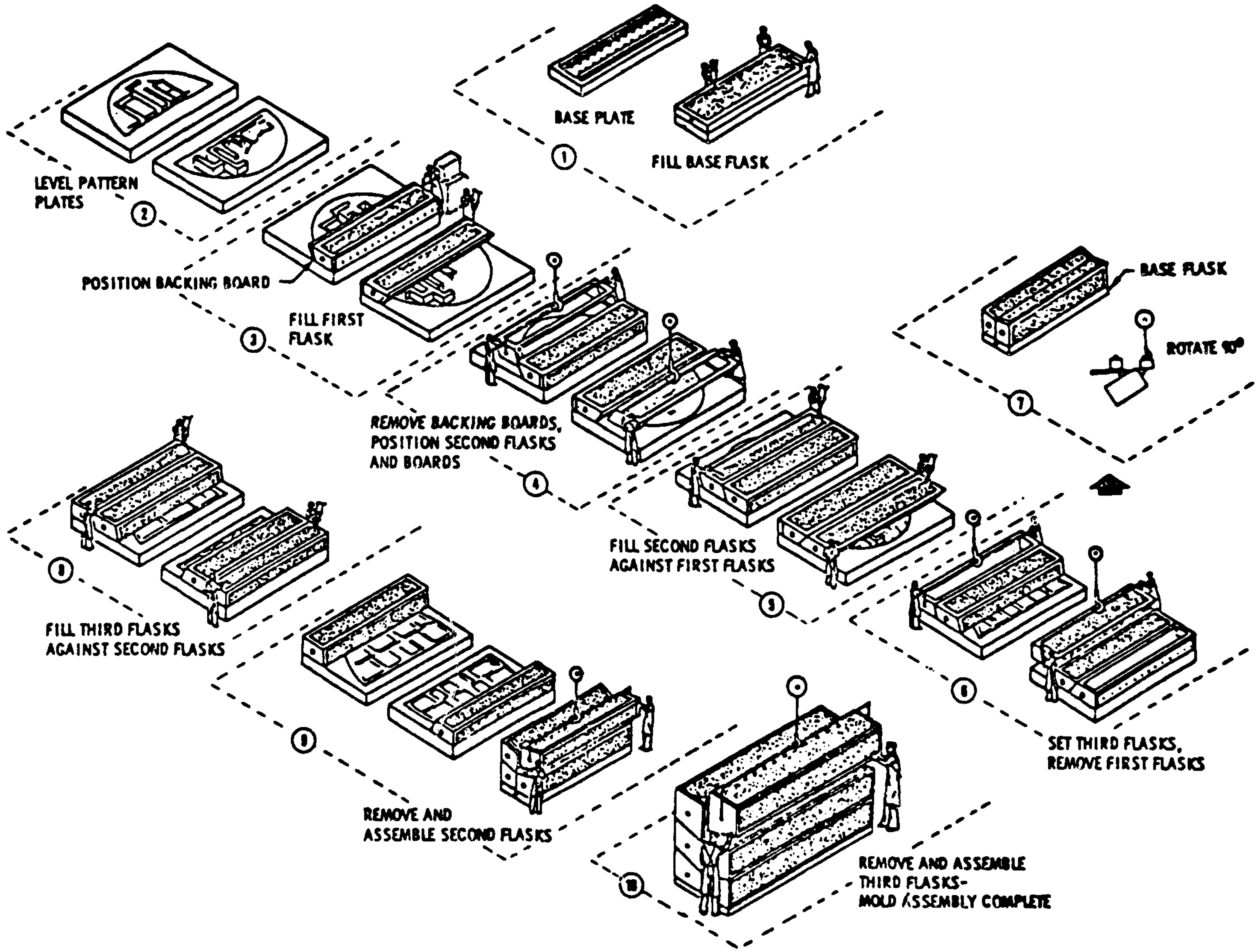


Figure 8 Mold Setup and Assembly Sequence

A draft angle of 2 degrees was provided on the vertical sides of each flask to allow for stripping from the pattern. The draft was machined into the ends prior to welding the horizontal channels in place. The flasks rested on machined steel plates, leveled to within 0.002 inch. The flasks then were held in place by standard foundry flask pins.

4. Cores and Core Placement

The mold consisted of 35 cores. Their locations are shown in Figure 9 for the aft side and in Figure 10 for the forward side. Core placement was done using core bolts rather than a paste. A mechanical means of fastening the cores was thought to provide a more consistent process. Bolt holes were provided in the cores. Wing nuts and washers were molded into the mold and the cores then were bolted securely in place.

5. Metal Requirements

The mold, as designed, required 1750 pounds of metal. This included the bulkhead, attached coupons, risers, gates, runners, sprues, and pouring basins. The primary consideration during the design of the mold was to consistently produce a high-quality casting. Consideration was given to using as little metal as possible, but not at the expense of quality.

B. PATTERN FABRICATION

1. Background

All pattern tooling used to fabricate the bulkhead was manufactured at Dependable Pattern Works, Inc. of Portland, Oregon. The tooling included the forward and aft match-plate pattern sections, base flask pattern, step gate patterns, backing boards, base plate, core boxes, and all flasks with necessary guide pins and bolts.

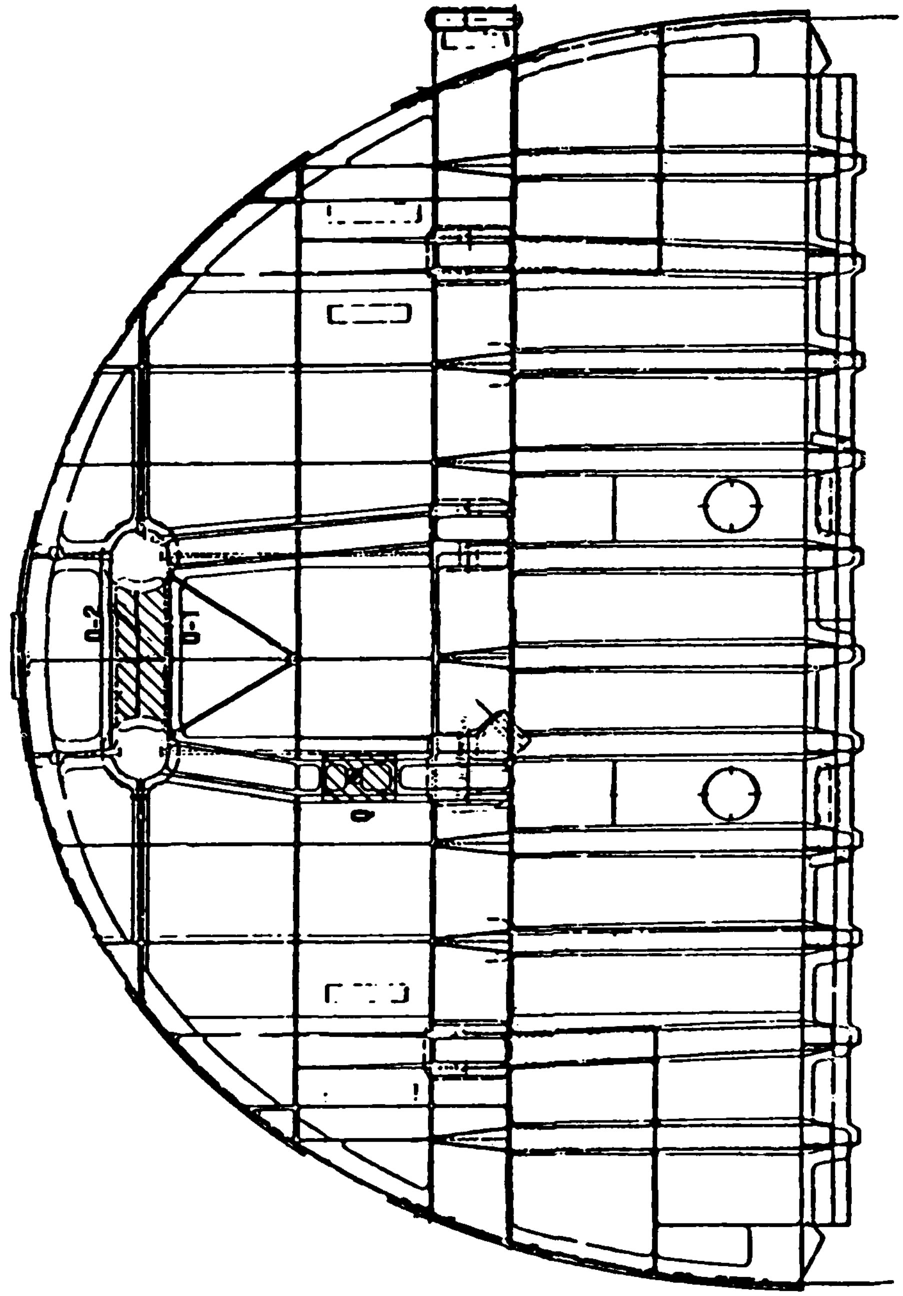


Figure 9 Core Locations - Aft Side

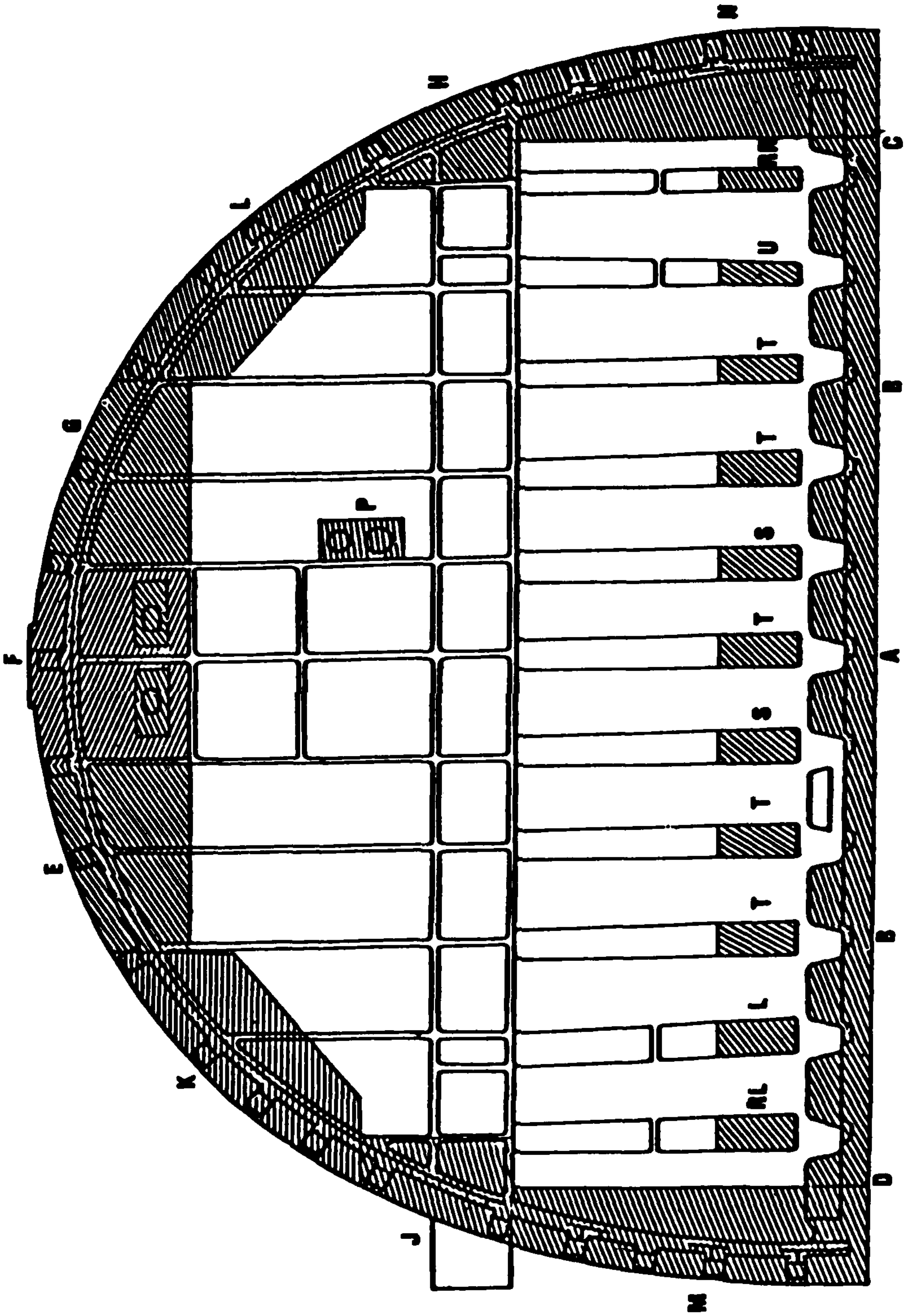


Figure 10 Core Locations - Forward Side

2. Pattern Materials/Allowances

Design of the pattern sections incorporated a 1/8-inch-per-foot shrinkage allowance according to established allowances for aluminum castings. The gating ratio used in the pattern design was 1:8:12, and a draft angle of 1.0 degree per side was incorporated for flask stripping from the pattern. Plastic materials and wood primarily were used in pattern fabrication in areas where strength was not a major consideration. Figure 11 shows initial pattern layout for the forward side of the bulkhead pattern using wood and plastic materials. All step gate patterns initially were made of wood, as shown in Figure 12. However, problems occurred during mold fabrication with breakage of the wooden step gate patterns, and the patterns were remade at Boeing from cast aluminum.

Pattern sections forming the webs or ribs on the bulkhead casting were made from sheet aluminum as shown in Figure 13 because of strength requirements of those sections. Core boxes for the bulkhead mold also were made with plastic and wood materials, as shown in Figure 14.

C. *MOLD FABRICATION*

1. Pattern Preparation

Prior to mold fabrication, the pattern sections shown in Figure 15 and base plate for the bulkhead casting were leveled optically with leveling telescopes and bubble levels to within 0.005 inch. With the exception of the torque-box internal cores (O-1, O-2) shown in Figure 9, all mold sections were made with a three-part air-set binder system consisting of Ashland "Linocure" AW, BW-3, and Part C. All air-set sand contained 1.1% total binder content and was prepared in a continuous mixer. The torque-box internal cores were bonded with 3.5% sodium silicate-CO_2 to provide ease in shakeout operations. The molding sequence for the bulkhead castings is shown in Figure 8. Molding materials and molding procedures used were according to Sections 3.2-3.4 of the Manufacturing Plan (Appendix A).

Figure 11 Body Bulkhead Pattern Buildup - Forward Side

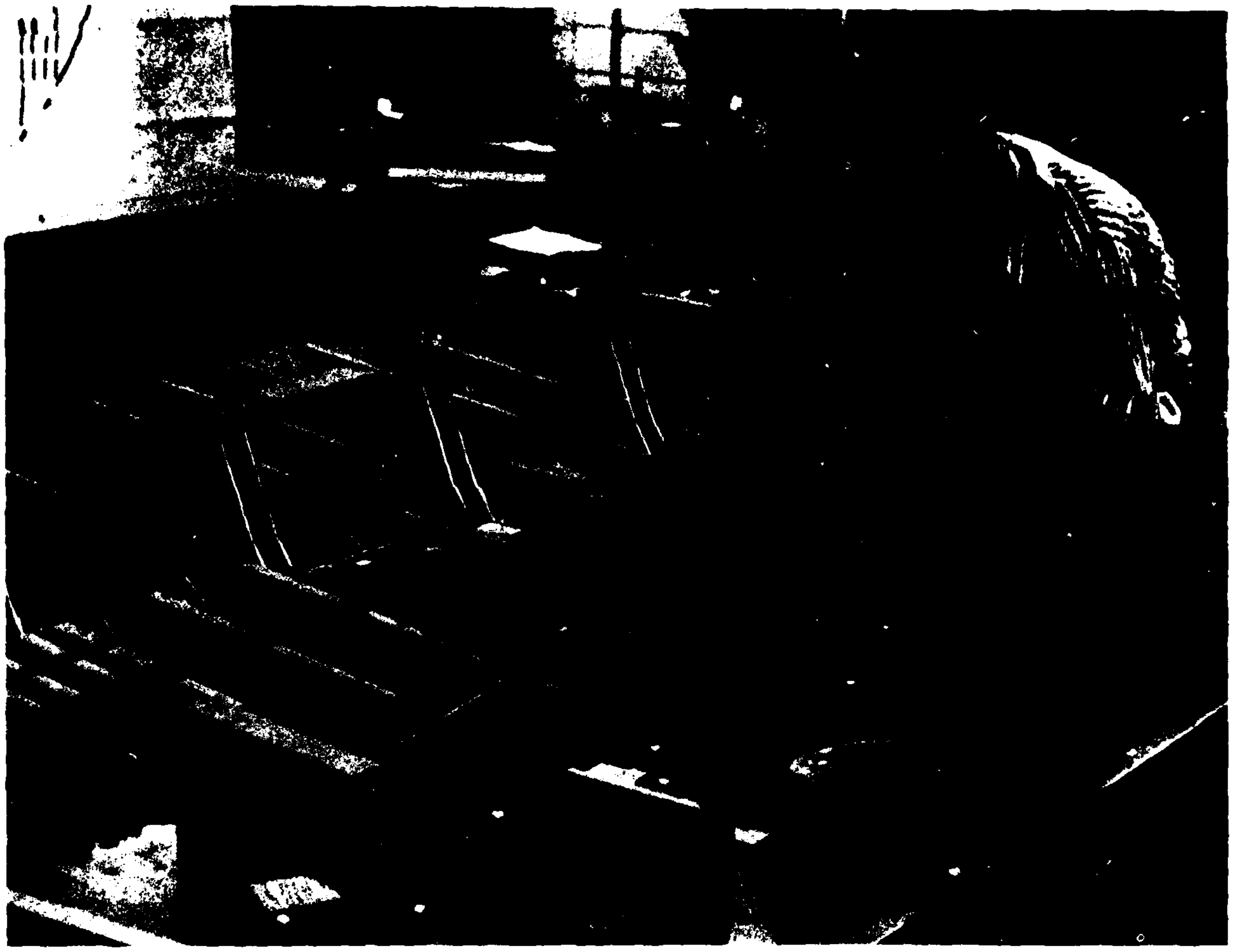


Figure 12 Step Gate Fabrication - Body Bulkhead Casting Pattern

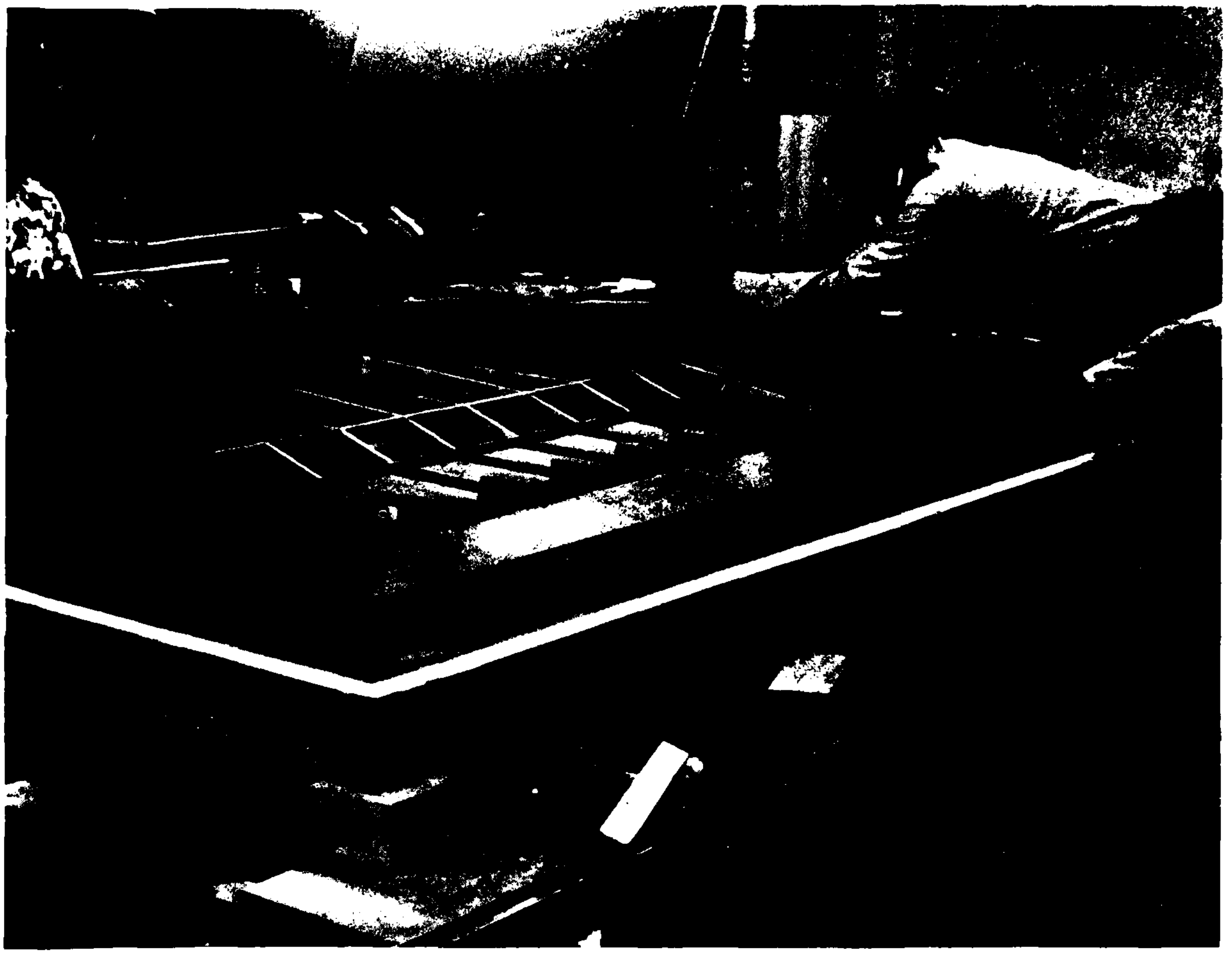


Figure 13 Sheet Metal Pattern Web Sections - Forward Side

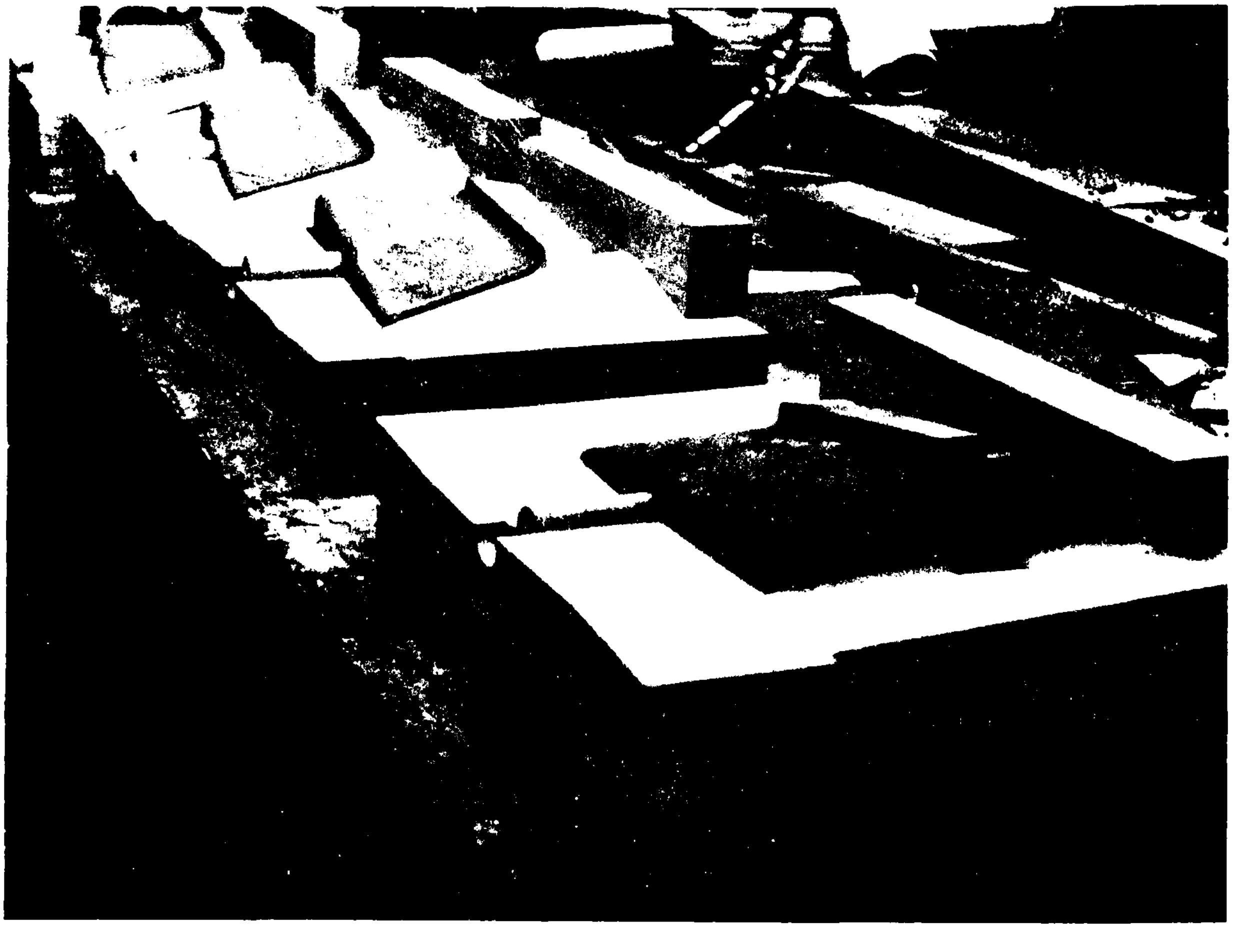


Figure 14 Core Box Fabrication - Body Bulkhead Casting Pattern

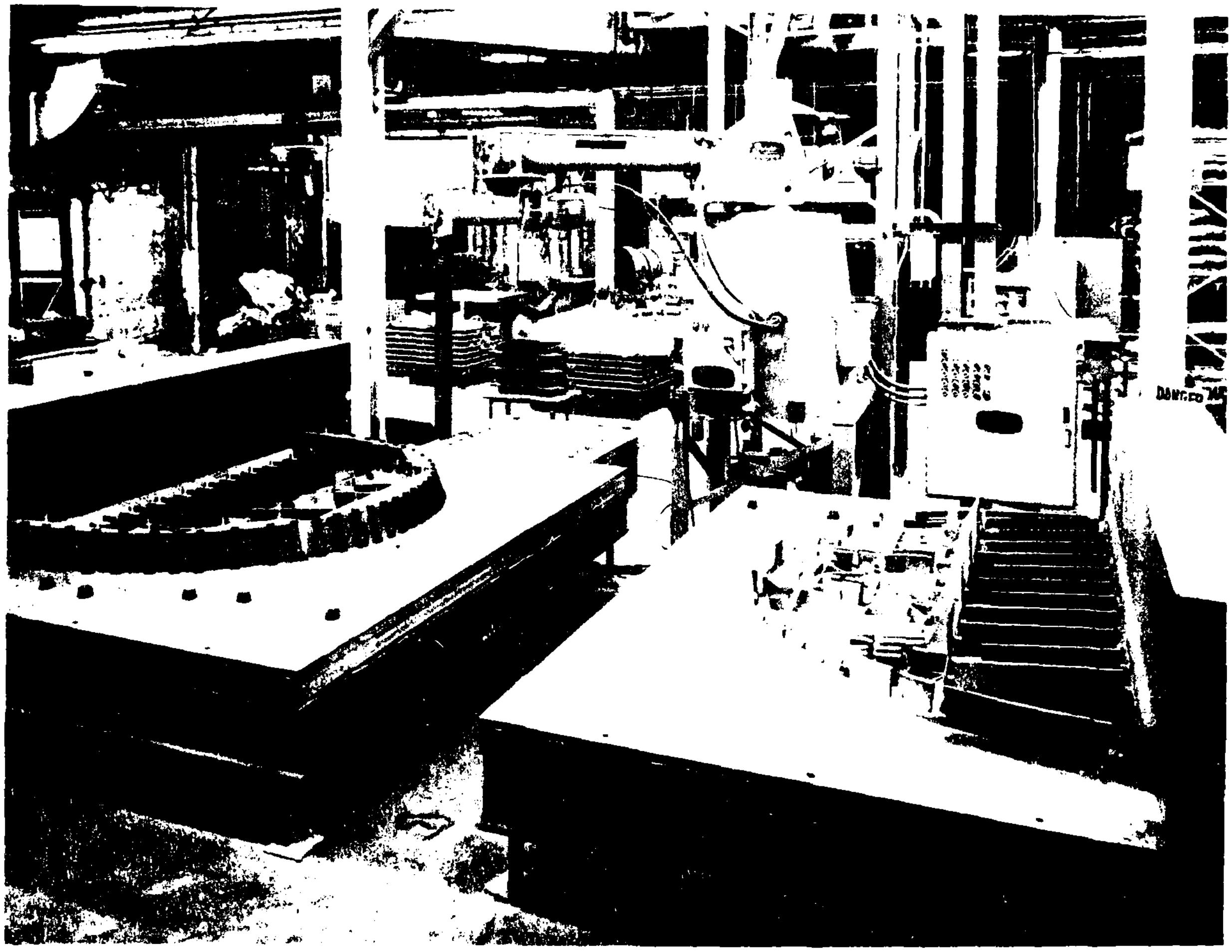


Figure 15 Forward and Aft Sides of YC-14 Station 170
Body Bulkhead Pattern

Before depositing any molding sand in the pattern flasks or core boxes, a coating of Ashland LP-16 "Zip-Slip" parting agent was spray applied to all surfaces in contact with the molding sand. Chills located inside the core boxes and on the aft and forward sides of the bulkhead mold also were positioned before molding. The chill locations and materials for the aft side of the bulkhead mold are shown in Figure 16. Those for the forward side are shown in Figure 17.

2. Molding

The mold base flask contained approximately 4800 pounds of molding sand (AFS 70 silica) and incorporated the two bottom runner systems. Each runner was lined with 3/4-inch-thick ceramic foam insulation and had tin-plated steel filter screens located in each pouring well. A completed base flask section is shown in Figure 18. Immediately before mold assembly, the surface of the base flask section that would be in contact with the molten aluminum was coated with amorphous carbon. In addition to the tin-plated steel screens in the pouring wells, steel wool also was positioned in the wells to minimize turbulence and oxide formation in the molten aluminum as it filled the runner systems.

Each of the flasks forming the mold cavity was filled with molding sand according to the sequence described in Figure 10. Each flask was located on the pattern with flask guide pins and was clamped to the neighboring flask to inhibit side movement. Prior to filling the flasks with sand, and after parting agent was applied and chills were positioned, the cores forming the cascading sprue were positioned. Figure 19 shows the positioning of a "ram-up" sprue core on the pattern prior to molding of the complete flask section. Figure 20 shows the forward side of the mold with the sprue cores in position before stripping operations.

The gating and risering system in the bulkhead mold was assembled during the molding of each flask section. The step gate locations for the aft side of the bulkhead casting are shown in Figure 6, and locations for the forward side are shown in Figure 7. The gating and risering network was formed in each flask by (1) filling the respective flask with molding sand to

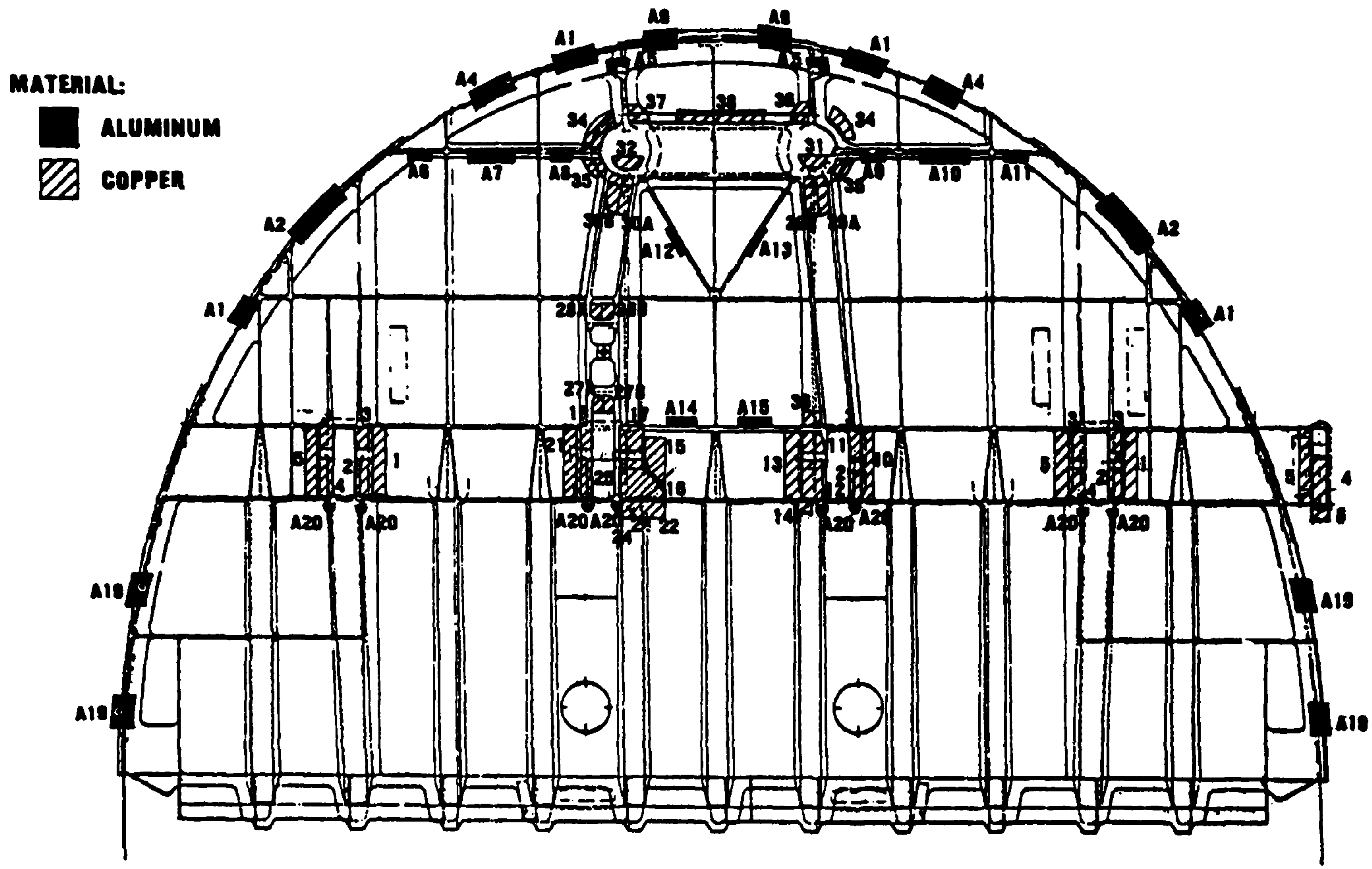


Figure 16 Chill Locations - Aft Side

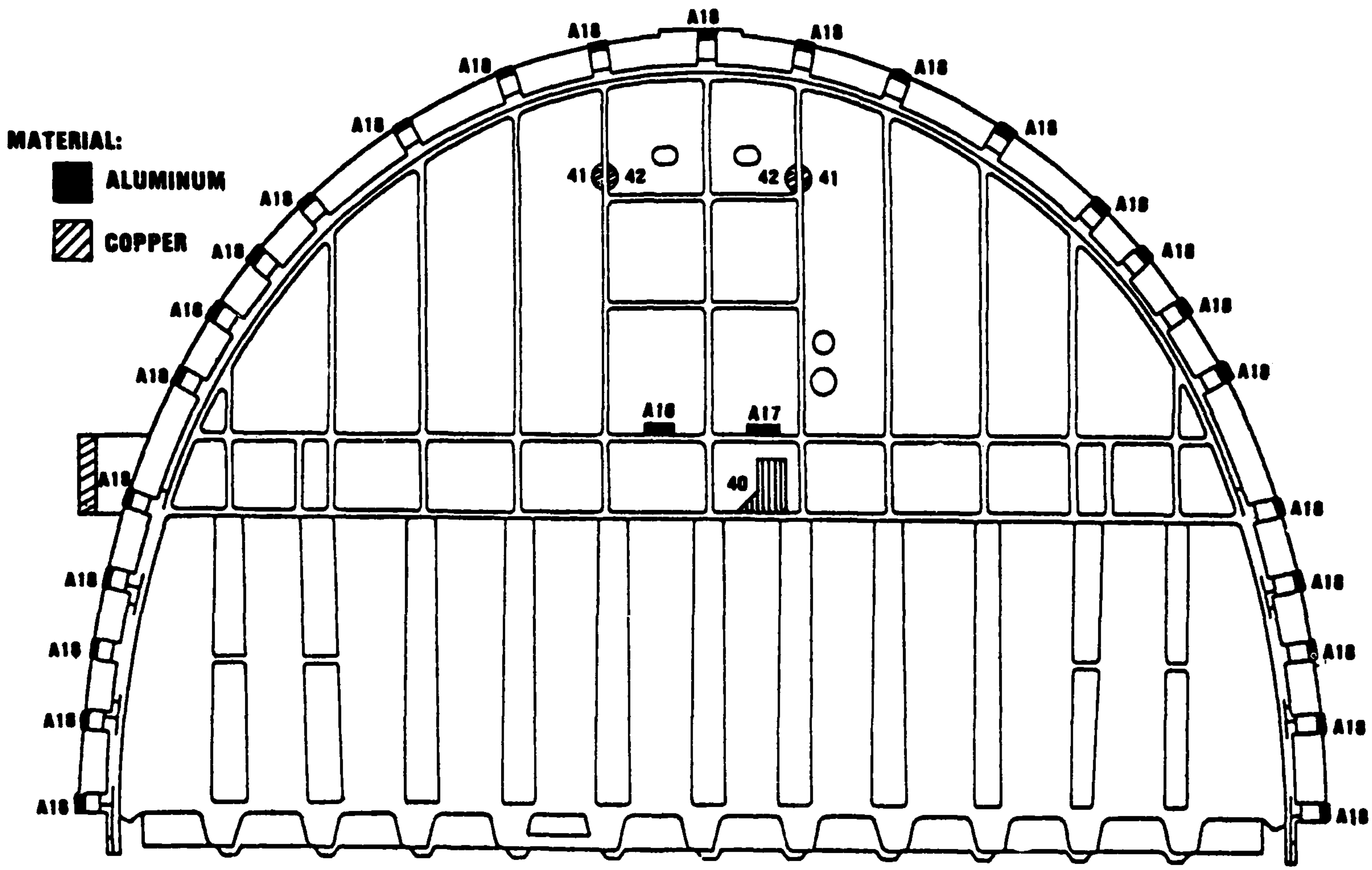


Figure 17 Chill Locations - Forward Side

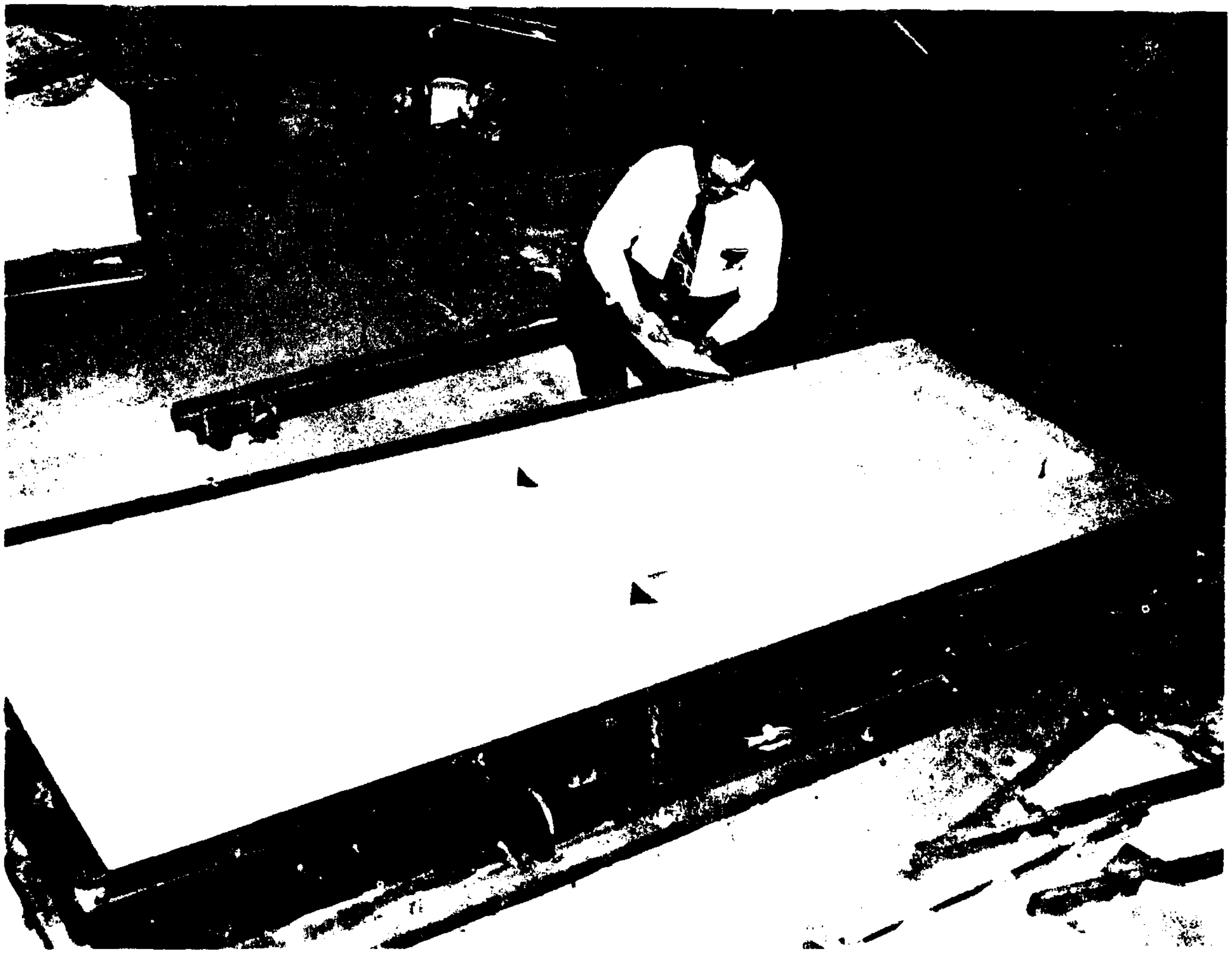


Figure 18. Completed Base Flask

Figure 19 Ram-up Sprue Core Placement - Aft Side

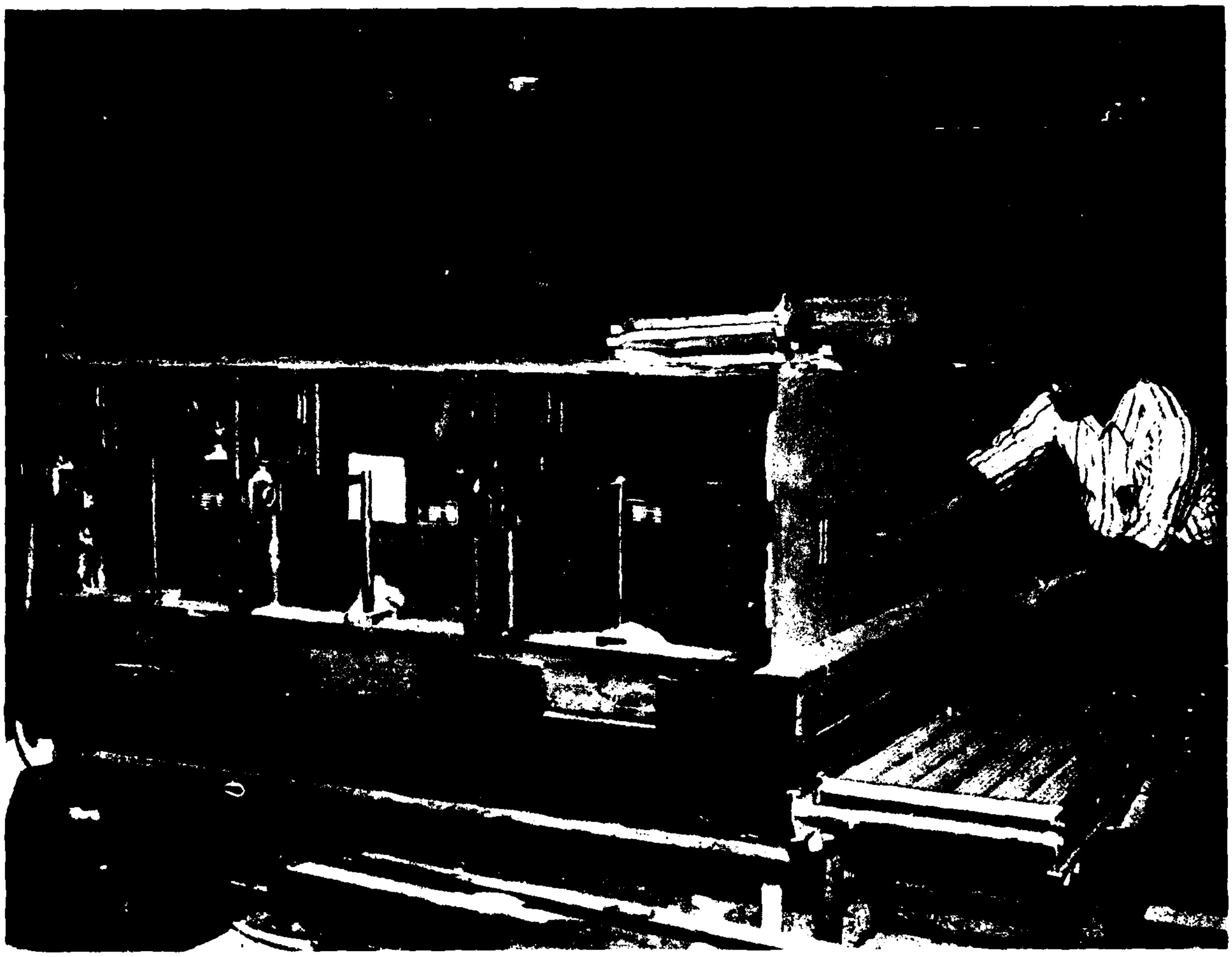


Figure 20 Molded Flasks Ready for Stripping - Forward Side

the top of the step gate patterns, (2) removing the gate patterns while the sand was still plastic, (3) positioning the screening material and riser sleeves over the step gate openings, and (4) back filling with molding sand. Figure 21 shows the removal of the step gate patterns from the molding sand. Figure 22 shows the positioning of the filter screens over the step gate openings, and Figure 23 shows riser sleeve placement over the screen. Because the sand was allowed to partially set up during the stripping operation of the step gate patterns and the screen and riser sleeve placement, reinforcement was required to hold the molding sand in the flask together. Cast aluminum gaggers were placed in the sand at varied locations after sand was deposited to the top of the step gate patterns. Figure 24 shows the approximate gagger locations for the aft side of the bulkhead mold, and Figure 25 shows the locations for the forward side.

Because of the thin pattern wall thickness (0.100 inch) and the complexity of the bulkhead pattern, special precautions were necessary in flask stripping operations. Typically, large flask sections may be removed from patterns with the use of spreader bars and overhead cranes. However, in addition to this stripping technique, flask/mold removal from the bulkhead patterns required the use of hydraulic jacks and alignment braces to ensure perpendicular movement of the flasks away from the pattern face. Hydraulic jacks were placed at the four corners of each flask, and the alignment braces were positioned against the flask edge (at both ends) to reinforce the flask guide pins and prohibit horizontal movement. An overhead crane and spreader bar assembly was used to support the load of the molded flask as it was raised from the pattern surface by the hydraulic jacks. All four hydraulic jacks were raised in unison, and the position of the flask during removal was checked with a bubble level. Figure 26 shows a typical flask removal operation for the bulkhead mold.

Each flask was sequentially stripped from the pattern and rotated 90 degrees, and excess sand was trimmed away. In this rotated position, the appropriate cores were positioned in the flask sections and secured by nut and bolt assemblies. Because of the size of most of the cores in the mold, conventional methods of pasting the cores in position could not be used. Figure 27 shows the securing of one of the cores into a flask section.

Figure 21 Step Gate Pattern Stripping

Figure 22 Filter Screen Positioning Over Step Gate Openings

Figure 23 Riser Sleeve Positioning Over Step Gate Screens

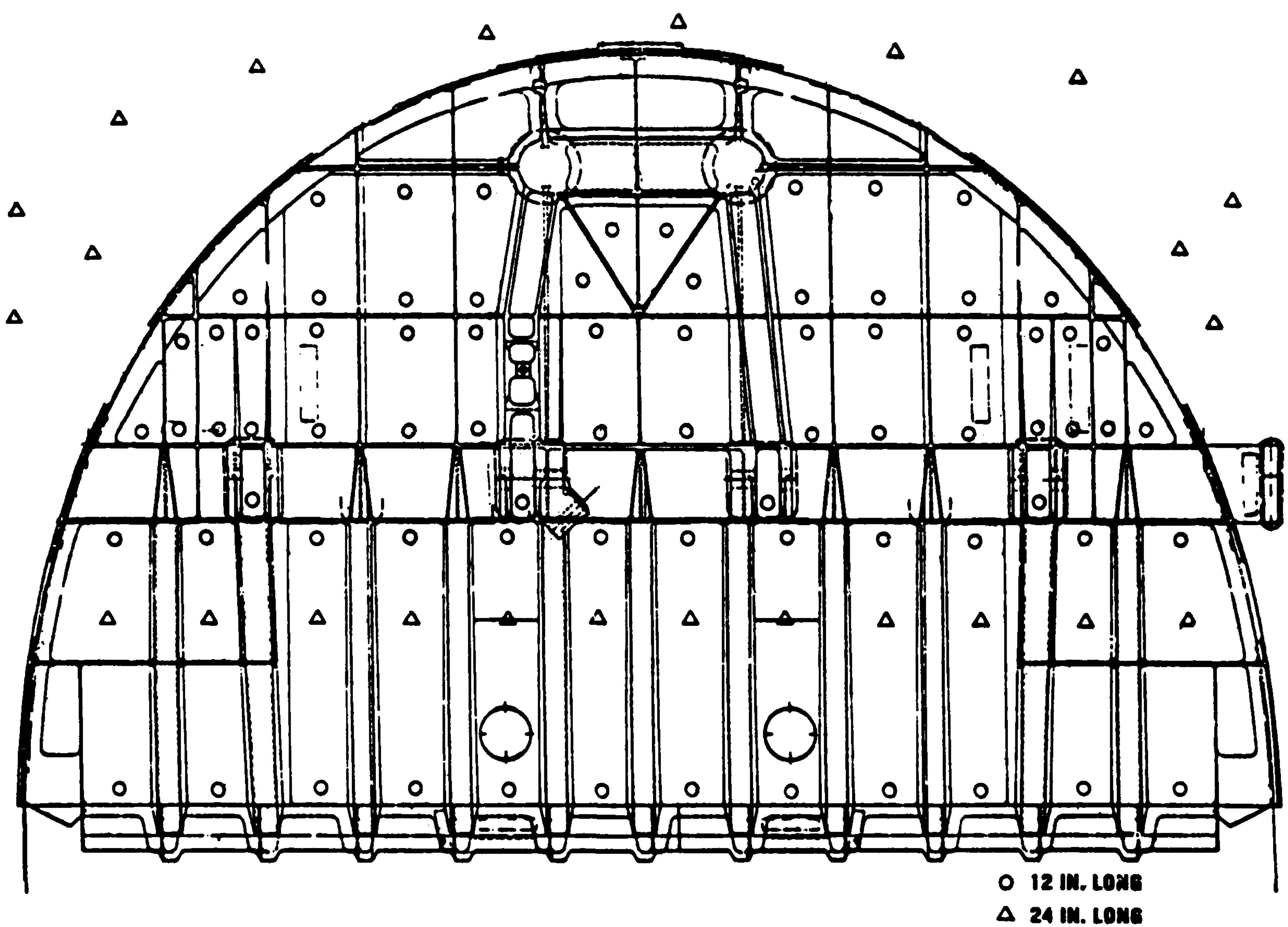


Figure 24 Approximate Gagger Locations - Aft Side

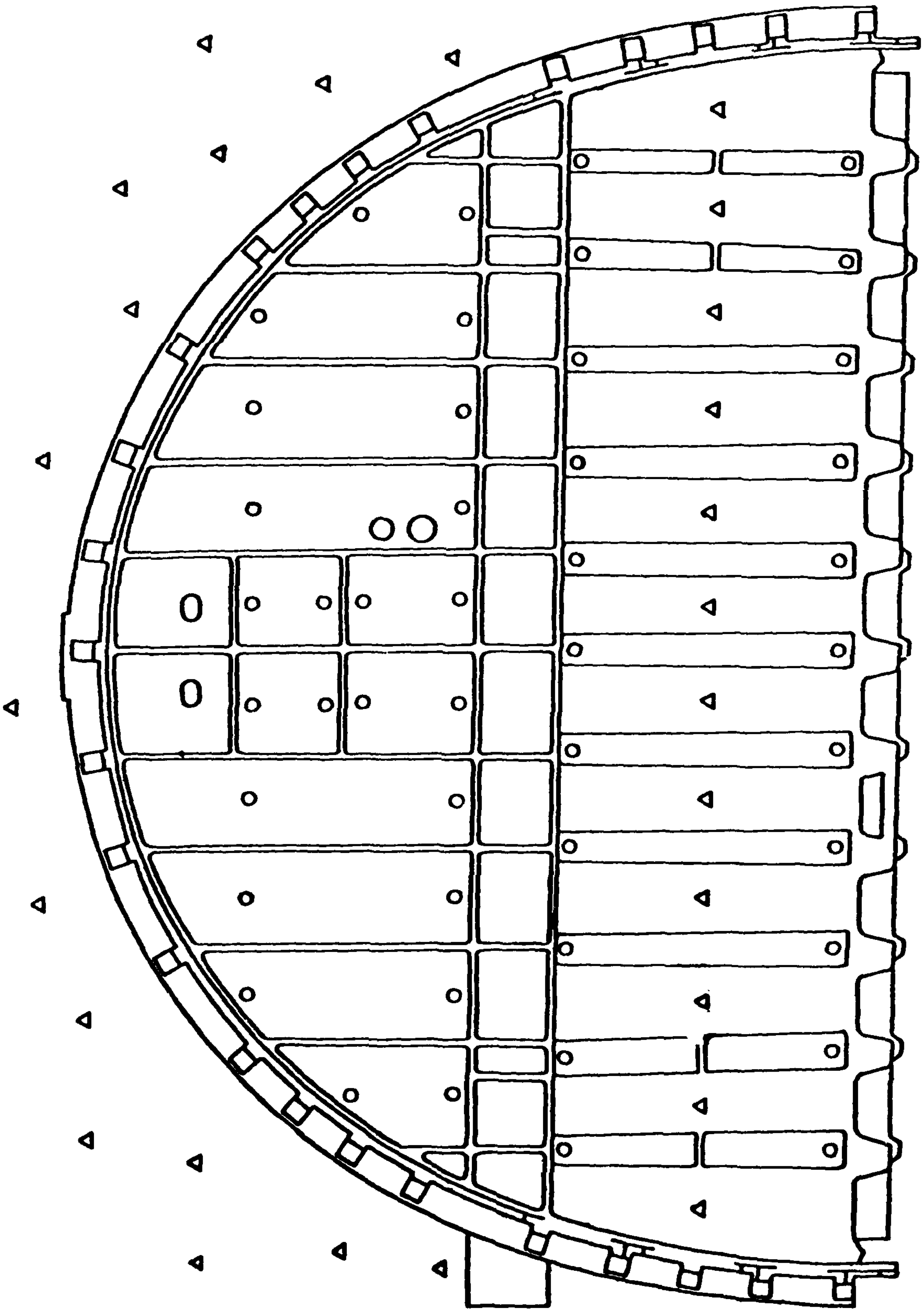


Figure 25 Approximate Gagger Locations - Forward Side

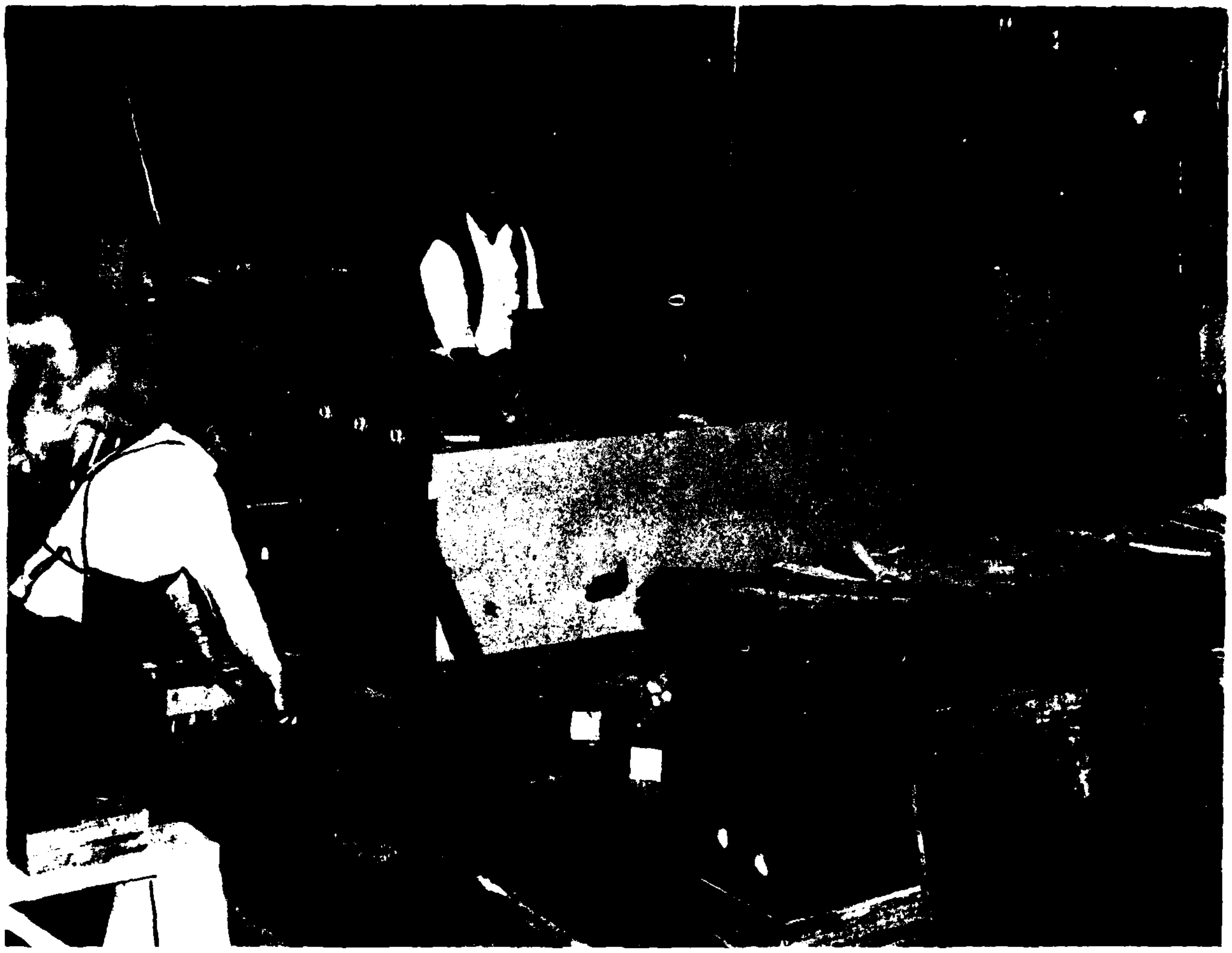


Figure 26 Flask Stripping Operations

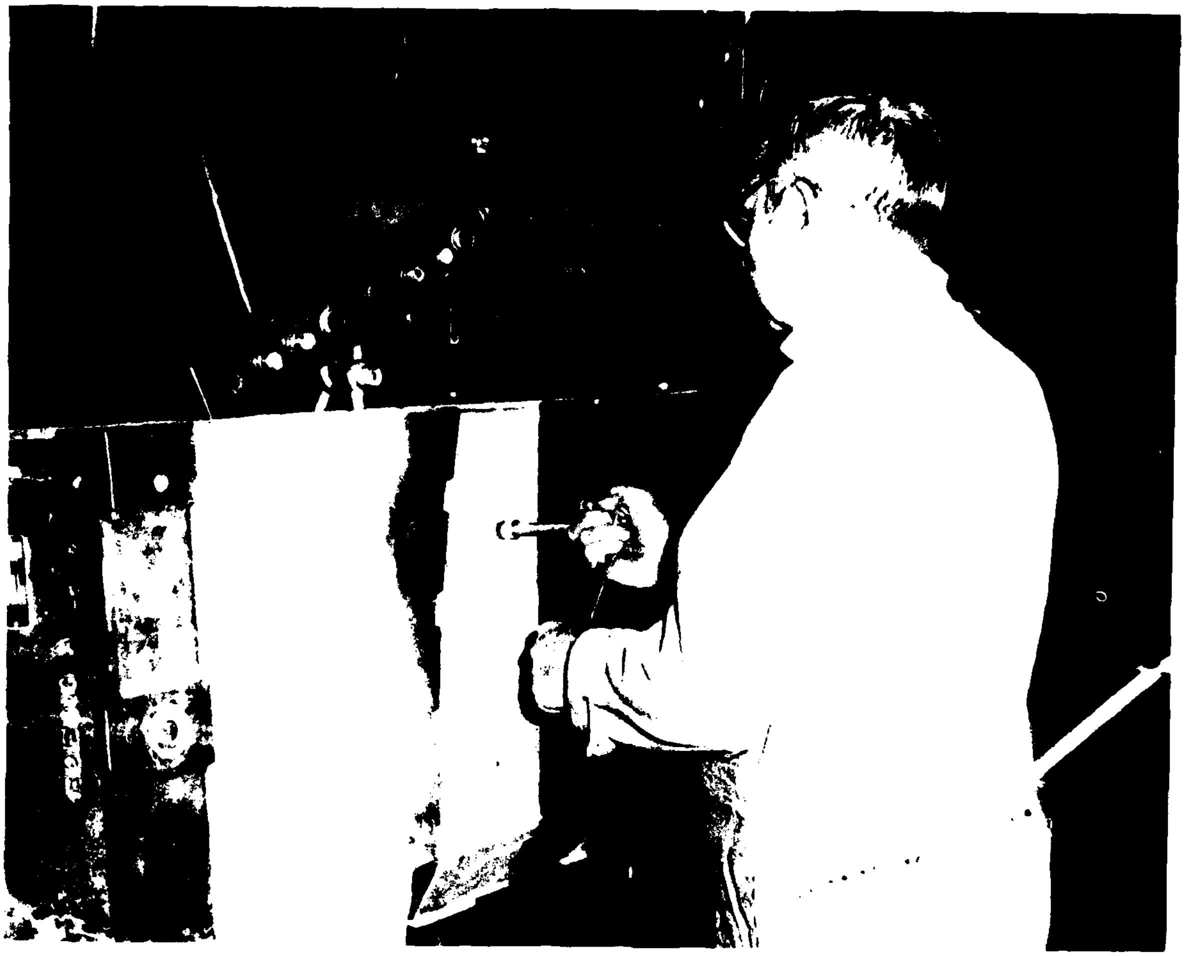


Figure 27 Securing a Core into an Aft Side Flask Section

After excess sand was cleaned from the flask sections and all applicable cores were secured in position, the sections were sequentially stacked on the base flask. To increase the fluidity of the molten aluminum as it filled the mold cavity, the surfaces of the mold that formed the mold/metal interface were coated with amorphous carbon with an acetylene torch. Figure 28 shows the application of amorphous carbon to the mold face. Because amorphous carbon also has an insulating capability, it was removed from all chill surfaces before stacking the next flask section.

As the flasks were stacked, each neighboring flask was bolted to the adjacent flask to form a single, monolithic flask/mold. Final assembly of the mold included placement of the pouring basins over the sprue openings and filling of all parting seams with sodium silicate bonded molding sand to inhibit run-out problems during pouring. Figure 29 shows a stacked bulkhead mold and filling of the parting seams, and Figure 30 shows pouring basin location and mold finishing.

D. MELTING AND POURING

1. Metal Preparation/Melting

Melting operations for each of the bulkhead castings were performed in 1000-pound-capacity gas-fired melting furnaces. Two furnaces were used, each containing approximately 960 pounds of metal. Each of the two melts consisted of B356.2 aluminum alloy adjusted to A357 composition per preliminary specification M-XXXX, Aluminum Alloy A357 Castings, Primary Aircraft Structure (Appendix D). To ensure clean base material, the B356.2 ingots and all alloy constituents were stored in a controlled area, separate from other foundry alloy lots. Melting operations were performed according to instructions outlined in Section 3.5 of the Manufacturing Plan (Appendix A).

2. Spectrographic Analysis

After melting, each heat was held at 1250-1300°F until mold and pouring preparations were complete. During this holding period, a molten sample

Figure 28 Coating the Mold Cavity with Amorphous Carbon

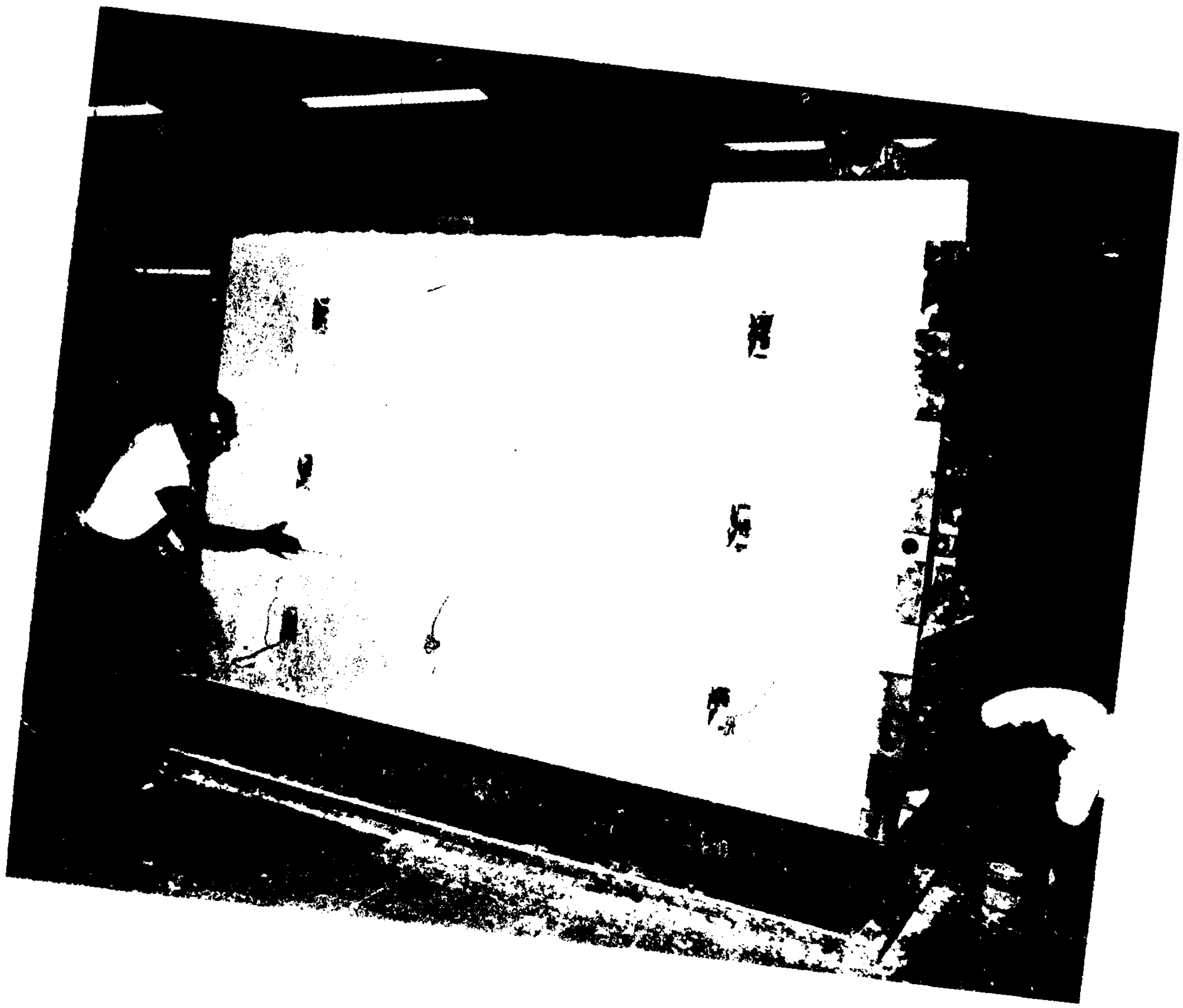


Figure 29 Stacked Body Bulkhead Mold - Filling the Parting Seams

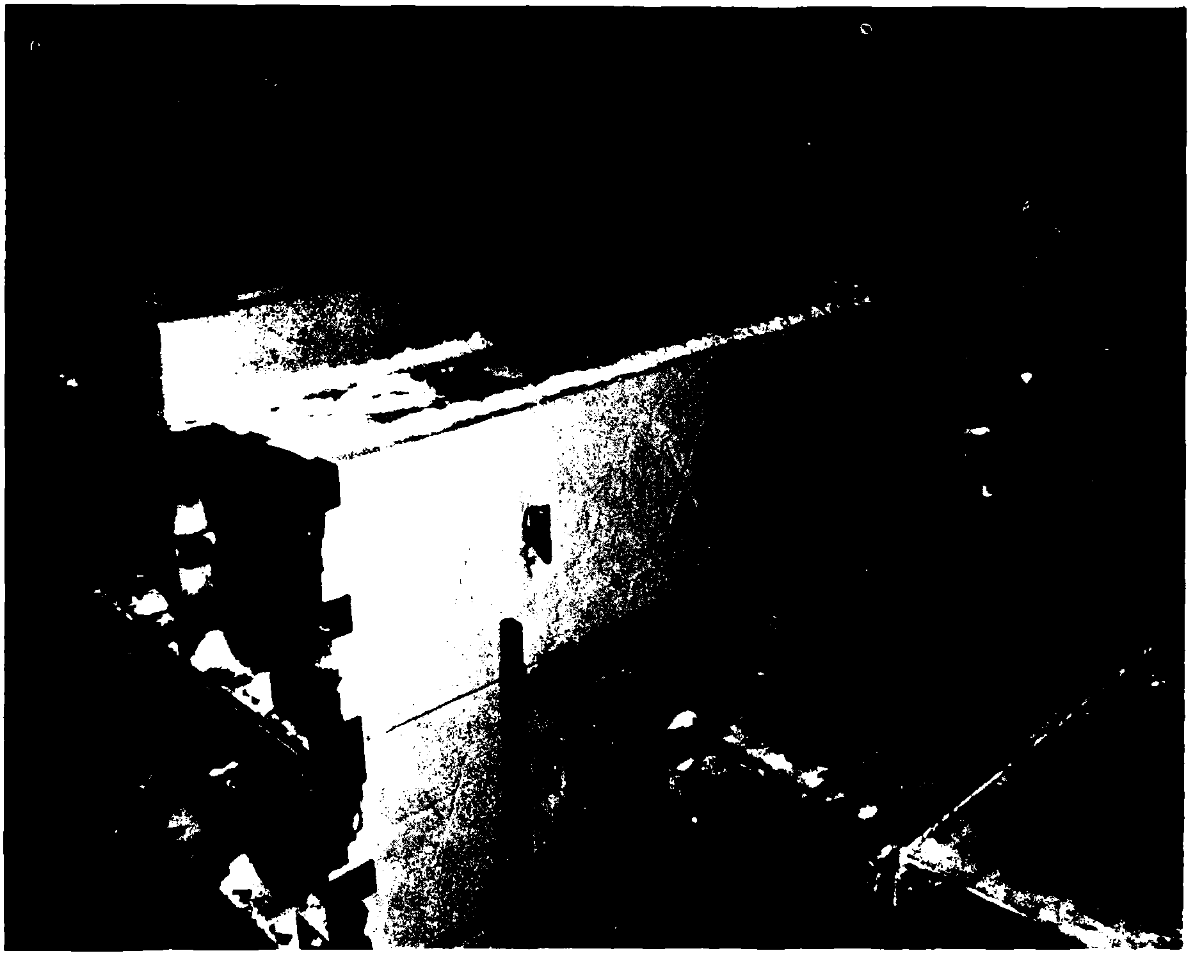


Figure 30 Pouring Basin Location and Mold Finishing

was taken (Fig. 31), allowed to solidify. and checked for proper chemistry by spectrographic techniques. If required, alloy additions were made and chemistry was rechecked before proceeding to degassing operations.

3. Degassing

After alloy composition was determined to be within the nominal limits of A357, the melt temperature of each furnace was raised to 1300-1325°F. Exact temperature of the molten charges was monitored by pyrometric controls on the power control panel of each furnace. At 1300-1325°F, each charge was purged with 90-95% nitrogen/5-10% chlorine gas mixture for 40 minutes (Fig. 32). The flow rate of the gas mixture into the molten aluminum alloy charges was adjusted so that the rolling action of the metal did not break the oxide layer on the surface of the melt. Upon completion of the degassing operation, each charge was allowed to set for about 15 minutes to allow all of the degassing media to come to the surface. After waiting 15 minutes, each charge surface was skimmed to remove dross. During both the degassing and skimming operations, graphite-coated utensils were used to avoid iron contamination of the charge.

Effectiveness of the degassing operation for each charge was determined by (1) removing approximately 3 ounces of molten aluminum alloy from each furnace with a heated crucible, (2) allowing it to freeze in a vacuum chamber under 27 $\pm$ 1 inches of mercury for 8 minutes and observing the exterior surface, and (3) sectioning the cooled specimen and examining interior surfaces. Figure 33 shows a sample being observed in the vacuum freeze chamber, and Figure 34 shows a sectioned specimen. If porosity was observed on the interior surfaces of the specimen, the charge was degassed again to remove trapped hydrogen and/or oxides. If bubbles broke on the exterior surface of the specimen during the initial stages of solidification, oxides were still present in the melt. If bubbles broke the surface during the final stages of solidification, there was hydrogen gas still present in the metal. In any case, sectioning of the specimen after solidification and examination the interior surfaces for gas or oxide defects determined the effectiveness of the degassing operation.

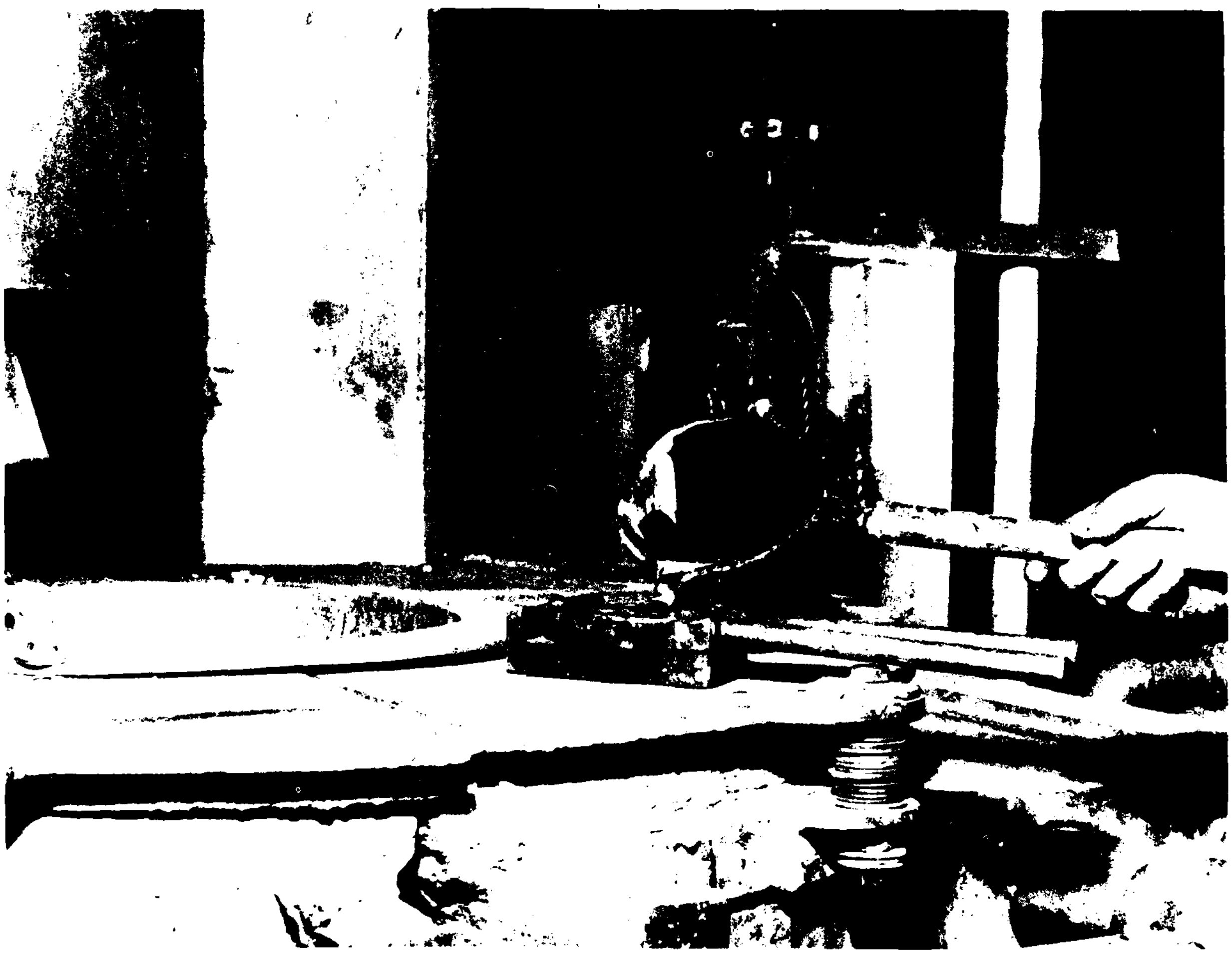


Figure 31 Taking a Molten Sample for Spectrographic Analysis

Figure 32 Degassing Operations - Purging the Melt with Nitrogen/Chlorine

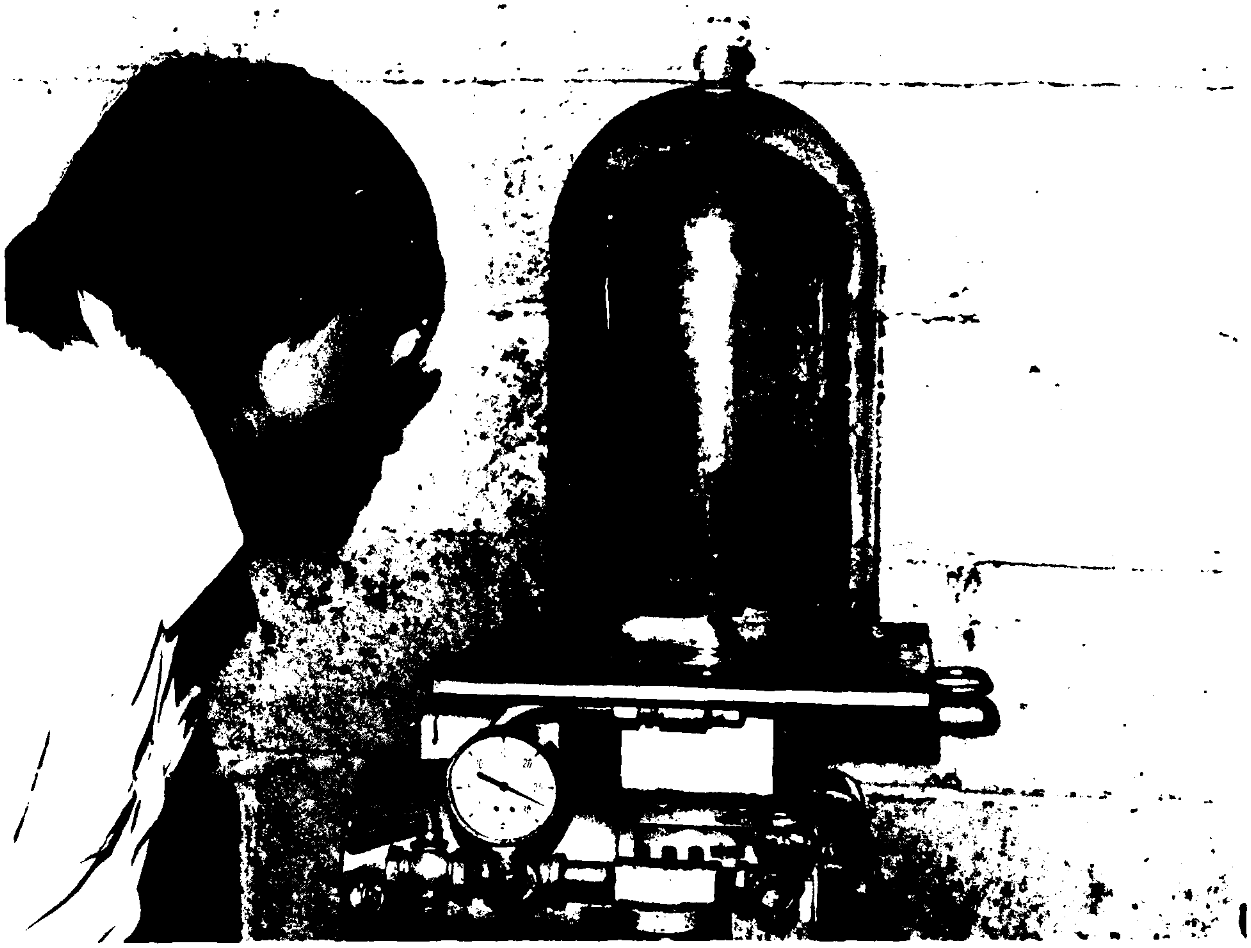


Figure 33 Vacuum Freeze Chamber - Gas Check

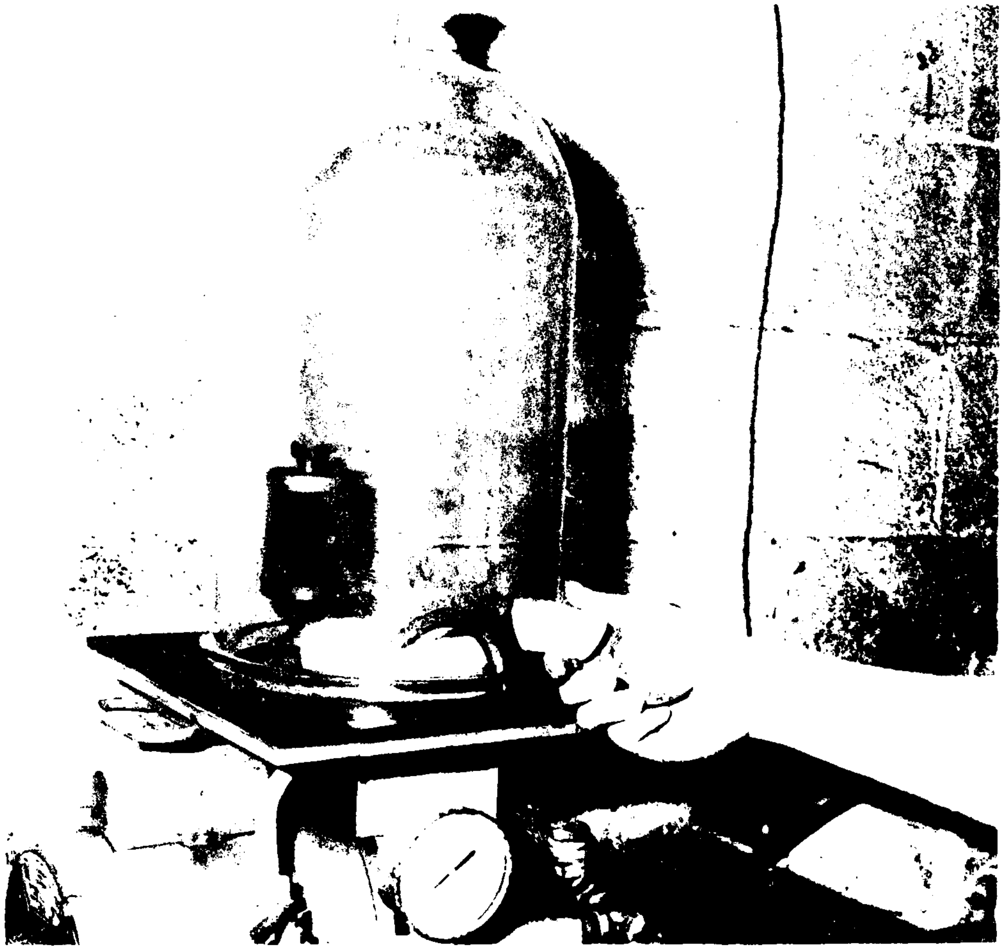


Figure 34 Checking a Solidified Specimen for Trapped Gas/Oxides

If trapped gas or oxides were still present in the charges after degassing operations, the operation was repeated for 20-30 minutes and rechecked. If the degassing operation was successful, the metal was poured within 2 hours of the final gas check. If more than 2 hours were expended between degassing and pouring operations, the degassing operation was repeated.

4. Ladle Preheat

Prior to tapping the furnaces, each of the two 1000-pound-capacity ladles used to pour the bulkhead castings was cleaned, coated with graphite wash, and then preheated to 1600 $\pm$ 50°F with natural-gas-fired lances. Each of the ladles was covered with an insulating lid to ensure retention of heat and was not allowed to cool lower than 1300°F before filling with molten metal. The temperature of each ladle was monitored with "Temp-stiks." During this preheating operation, mold preparations were completed and the temperature of the molten aluminum alloy in each furnace was raised to 1480 $\pm$ 10°F. When this temperature was obtained from each of the furnace charges, the oxides were carefully removed from the surface of each molten bath by skimming. Ladle preheat and pouring operations were according to procedures outlined in Sections 2.5.2-3.7 of the Manufacturing Plan (Appendix A).

5. Furnace Tapping

Furnace tapping was accomplished by positioning a preheated ladle below the pouring lip of each furnace and adjusting the angle of the ladle to equal that of the metal flow (Fig. 35). By adjusting the angle of the metal flow and controlling the rate at which the metal filled the ladle, turbulence and the resulting formation of oxides and gas could be minimized in the metal. When both of the ladles were filled (approximatley 960 pounds each), they were moved by crane to the mold. Immediately prior to pouring, each of the molten charges in the ladle was skimmed and a sample was taken for spectrographic analysis.

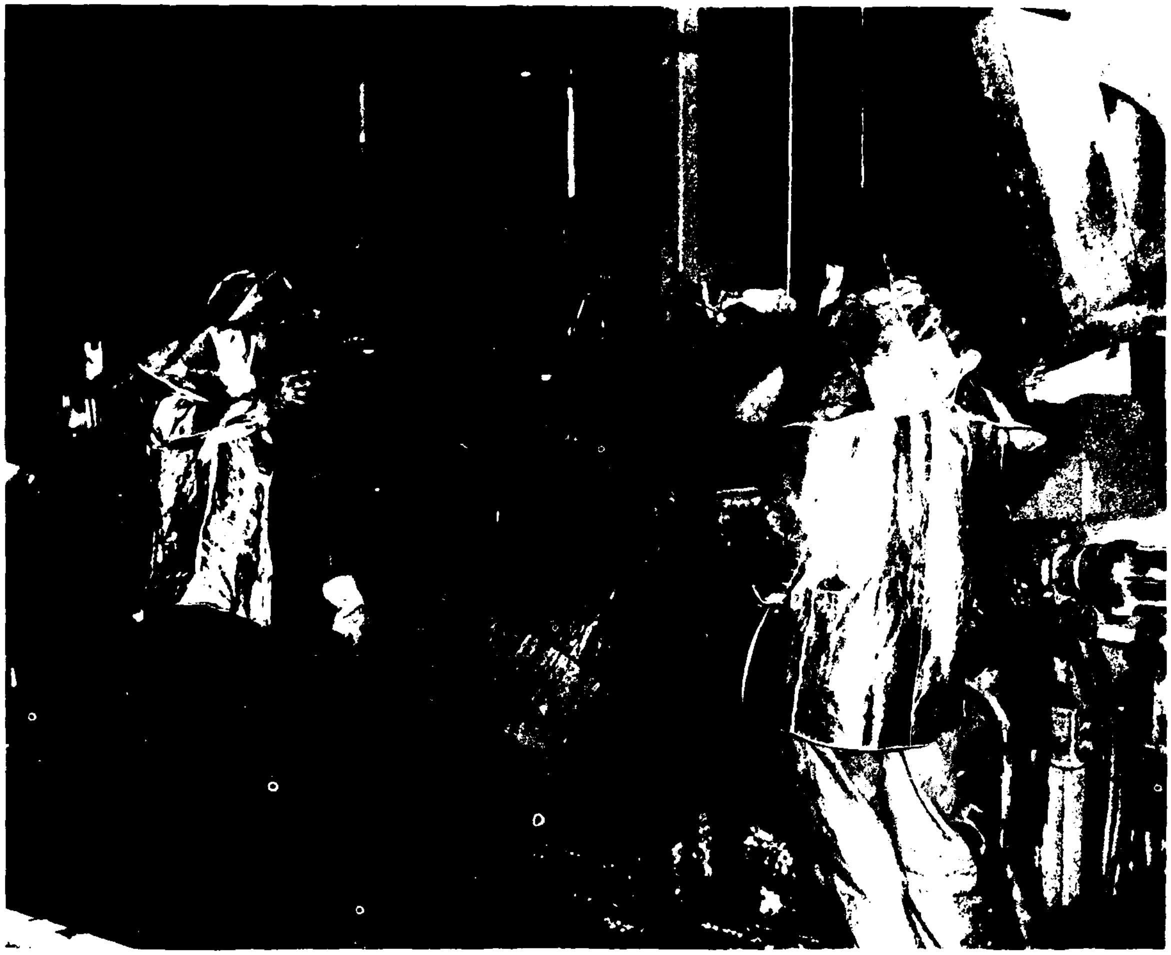


Figure 35 Furnace Tapping

6. Temperature Monitoring

Temperature monitoring of each of the filled ladles was achieved with portable immersion-type pyrometers. The pouring temperature for the bulkhead casting was 1440°F; temperatures below 1430°F were not sufficient for complete filling of the mold cavity. Figure 36 shows the type of pyrometer used in casting the bulkhead.

Because pouring of the casting at temperatures below 1430°F would not provide sufficient filling of the mold cavity, it was imperative that furnace tapping and pouring operations be performed as quickly as possible.

7. Mold Pouring

Each of the mold pouring basins for the bulkhead casting contained two plugs. These plugs, made from oil-urethane bonded molding sand, covered the sprue systems leading to the bottom and middle runner systems in the mold. After the pouring basins were filled, the basin plug cores for the bottom runner system were removed in unison (Fig. 37). The height of the molten aluminum metal filling the mold cavity was monitored by a battery-operated indicator light system (Fig. 38). Each of the runner systems contained electrical lead wires from the lighting system (Fig. 39). The ends of the lead wires were not connected, so that as the metal filled the runners, the molten aluminum surrounded the wires and completed the circuit. The indicator lights on the monitoring panel thereby showed the height of the molten aluminum as it filled the mold cavity. When the metal rose in the mold to a level slightly below the middle runner system, the plugs covering the middle sprue system were removed. Filling of the middle runners and successive mold filling were indicated by a third set of lights on the panel. Figure 40 shows monitoring of the light indicator panel during the pouring operation.

Throughout the pouring operation, the flow of molten aluminum and the angle of the pouring ladle were controlled to minimize turbulence in the pouring basins. Figure 41 shows actual pouring of the aluminum into a pouring basin.

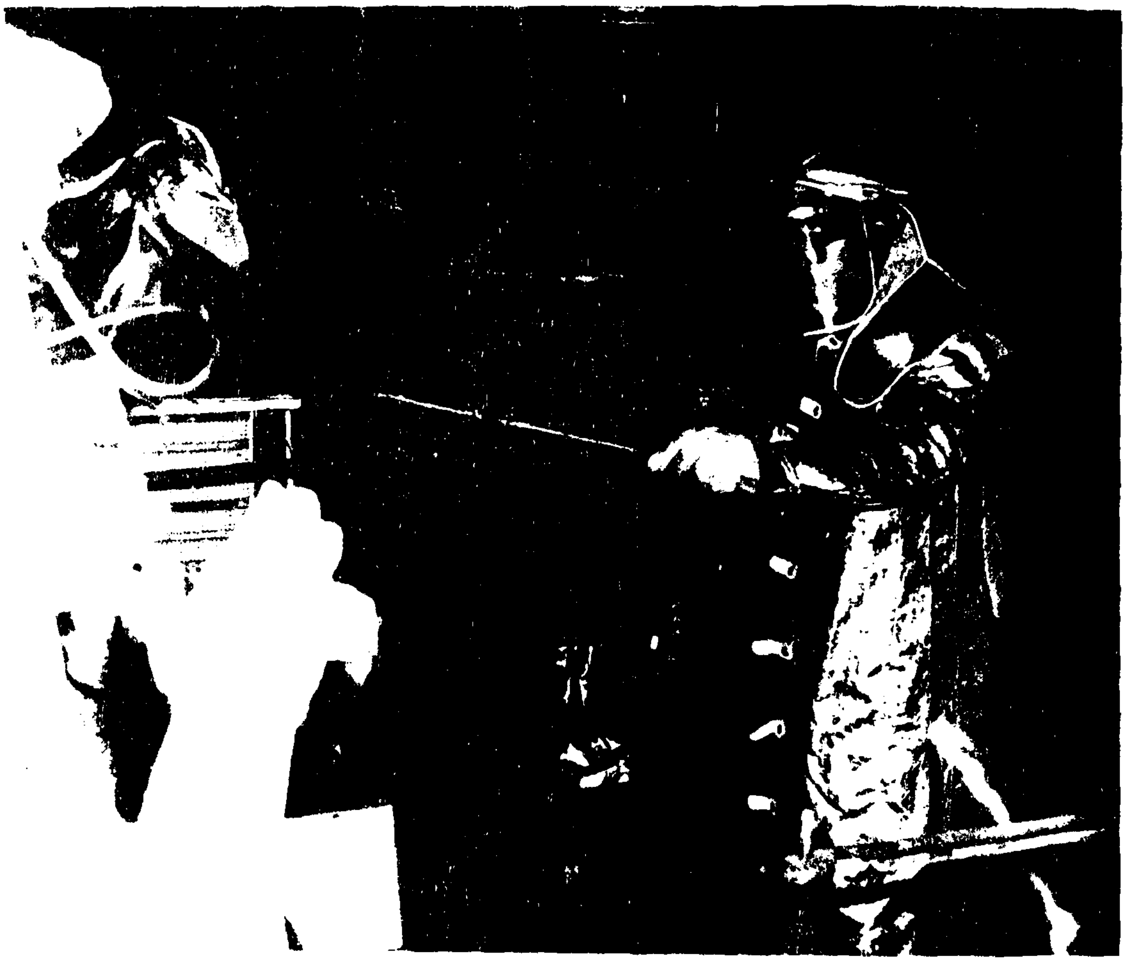


Figure 36 Temperature Monitoring with a Digital Immersion Pyrometer

Figure 37 Filling the Pouring Basin - Ready to Pull Sprue Plug

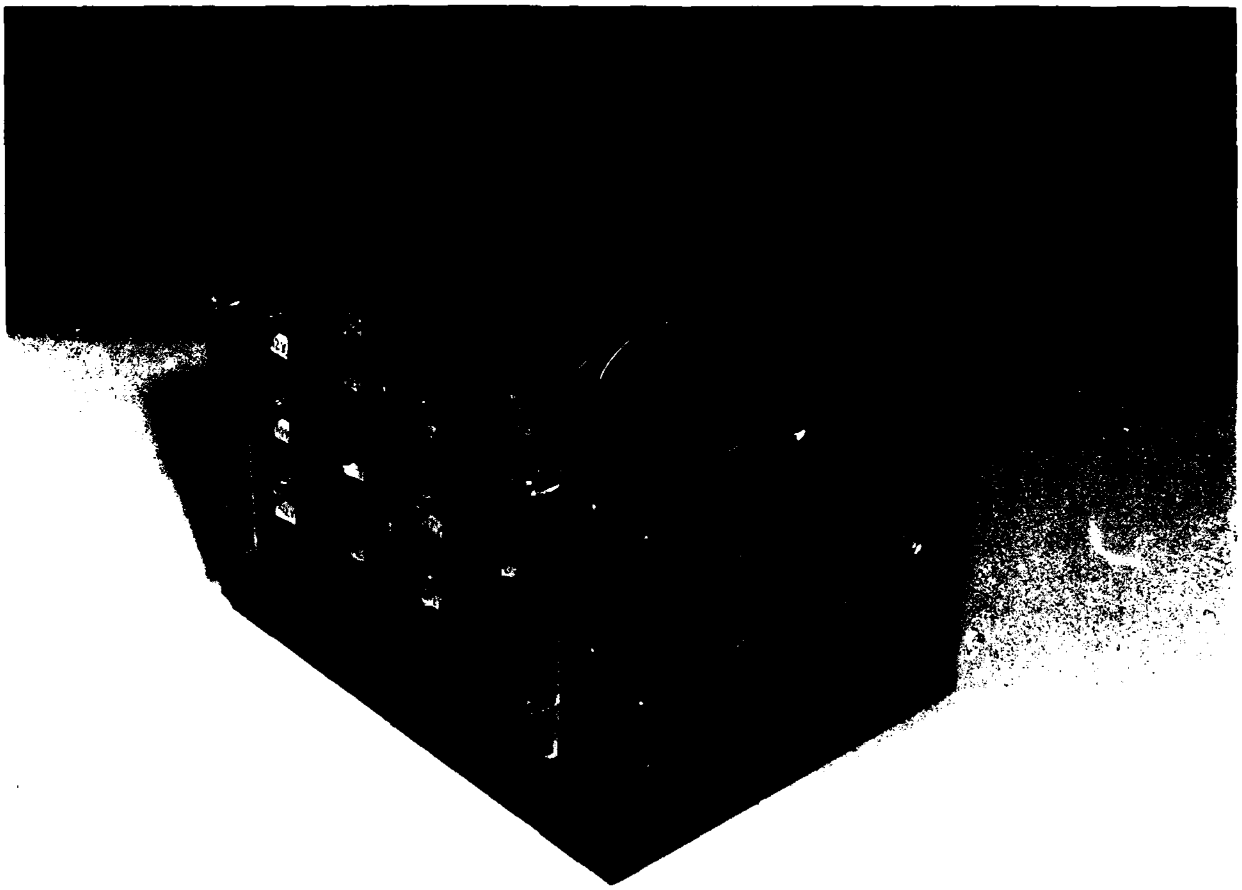


Figure 38 Metal Height Light Indicator Panel

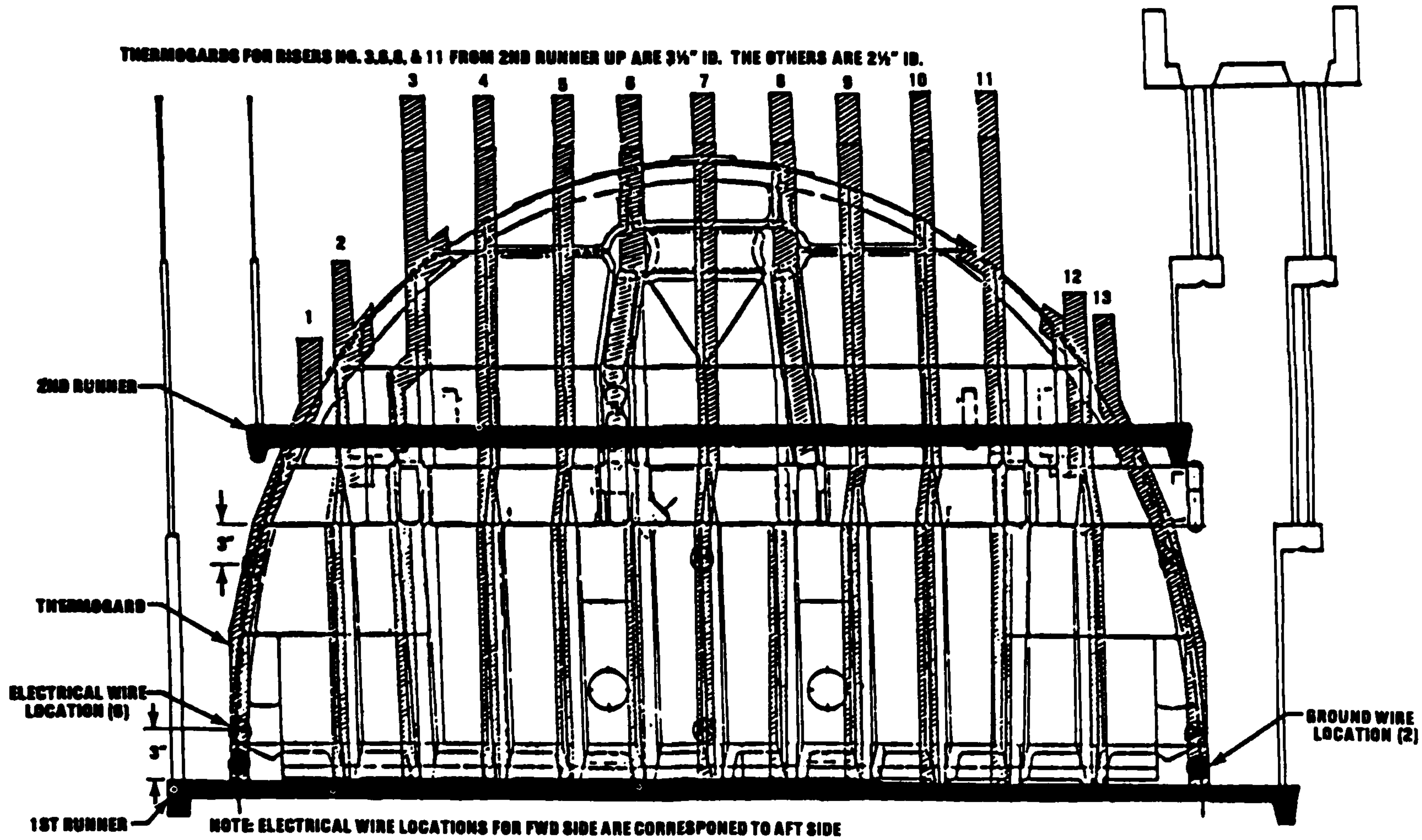


Figure 39 Electrical Wire Locations - Aft Side

Figure 40 Monitoring the Metal Height Light Indicator Panel
During Mold Pouring

Figure 41 Pouring the Bulkhead Casting

Upon completion of pouring operations, the ladles were removed from the mold area and any excess aluminum was poured into ingot molds. When the ingots had cooled, they were labeled and placed in a controlled storage area.

E. MOLD SHAKEOUT/TRIMMING OPERATIONS

1. Mold Shakeout

Mold shakeout operations typically began approximately 1 to 1-1/2 hours after pouring. The sand contained in the flasks was mechanically removed with chipping hammers and chisels to a depth of about 1/2 inch from the casting. The remainder of the sand surrounding the casting was removed by grit blasting. Figure 42 shows a bulkhead casting being cleaned by grit blasting. Shakeout and trimming operations performed on the bulkhead casting were according to procedures outlined in Sections 3.8 and 3.9 of the Manufacturing Plan (Appendix A).

2. Trimming

Removal of the risers and solidified step gates was accomplished with reciprocating saws. The step gates were cut off the casting so that only a minimum amount of material (1/4-1/8 inch) remained to be trimmed off. Figure 43 shows rough trimming of a bulkhead casting with reciprocating saws.

Flashing, surface burrs, and the remaining step gate material were removed with portable grinders as shown in Figure 44. To ensure traceability, each casting was identified with a respective part and sequence number by "Vibra-etch."

A summary of pertinent foundry data for the 10 Boeing castings is shown in Table 1.

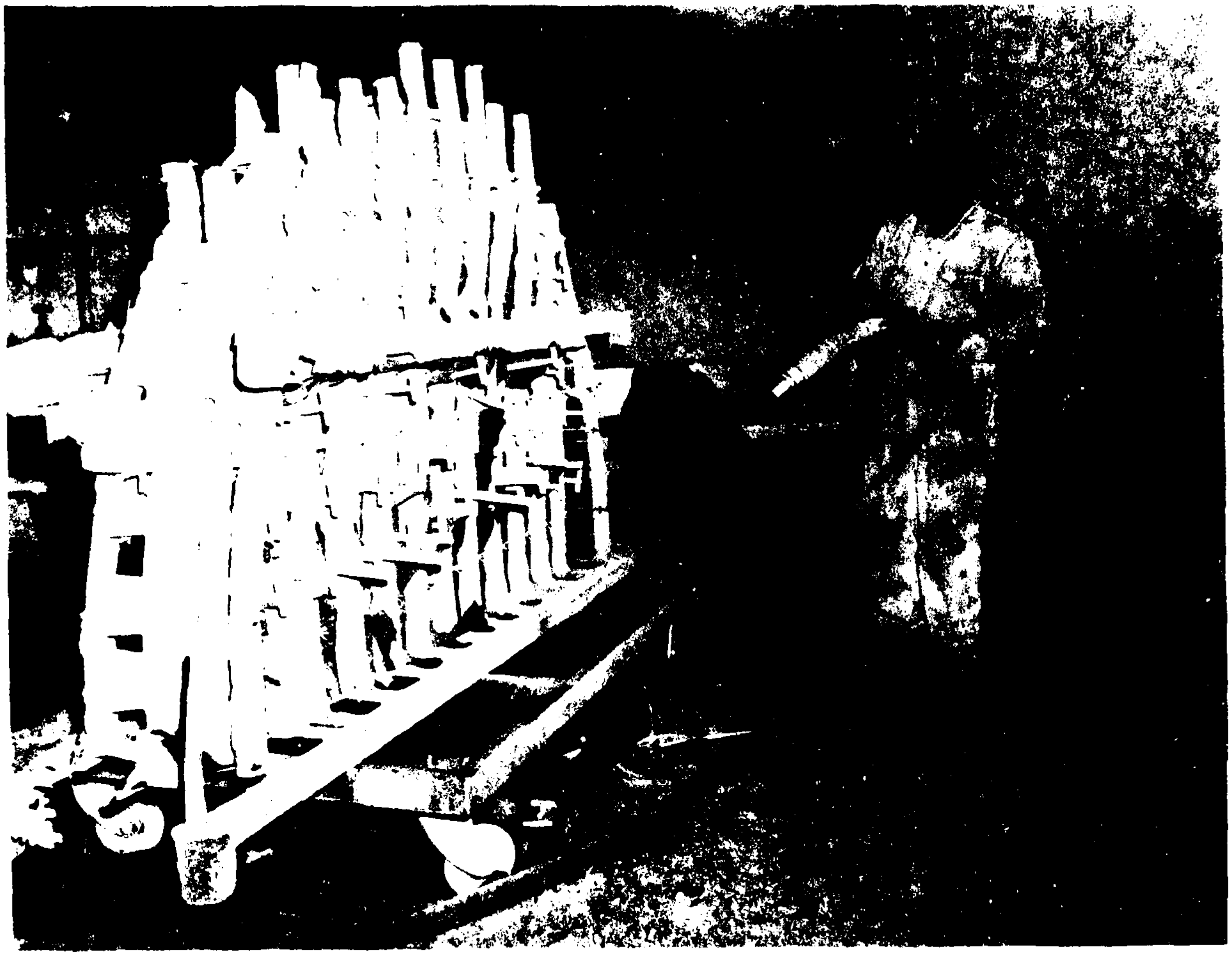


Figure 42 Grit Blasting Excess Sand from the Bulkhead Casting

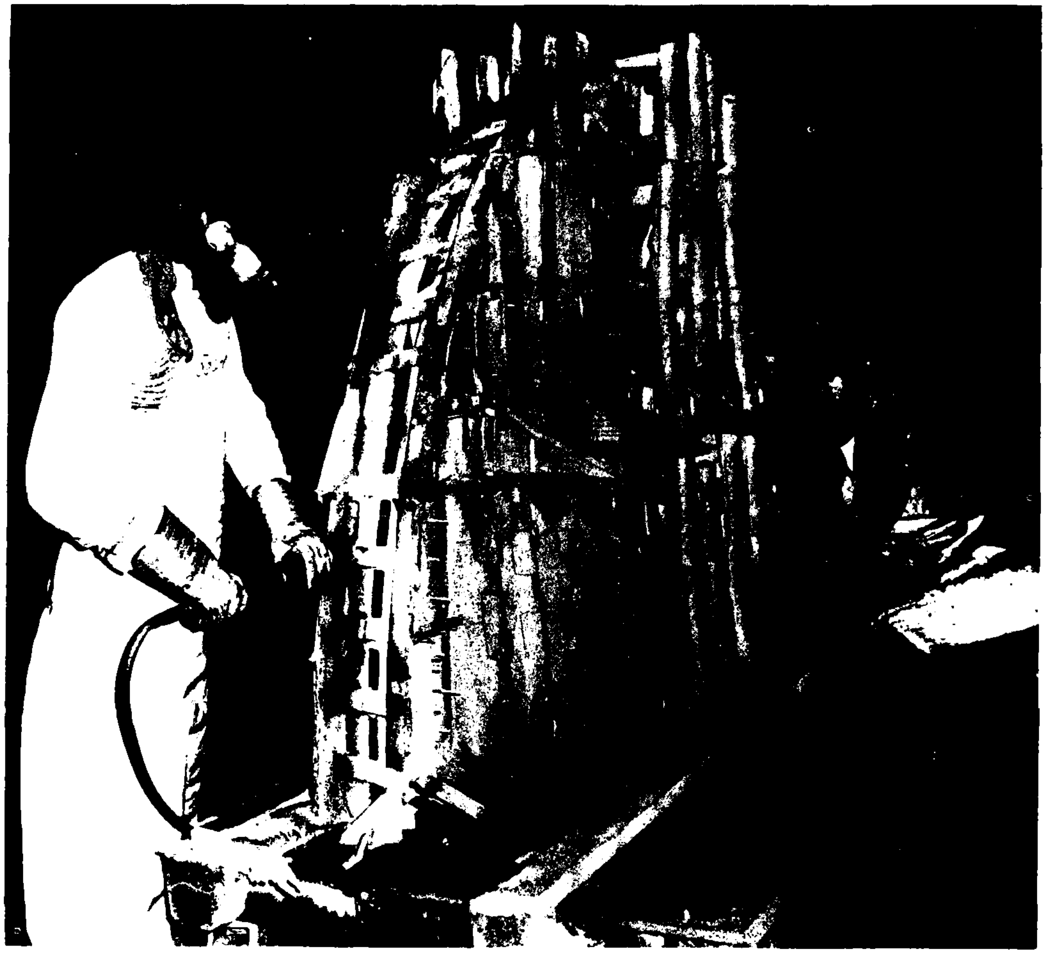


Figure 43 Rough Trimming Gates and Risers from the Bulkhead Casting

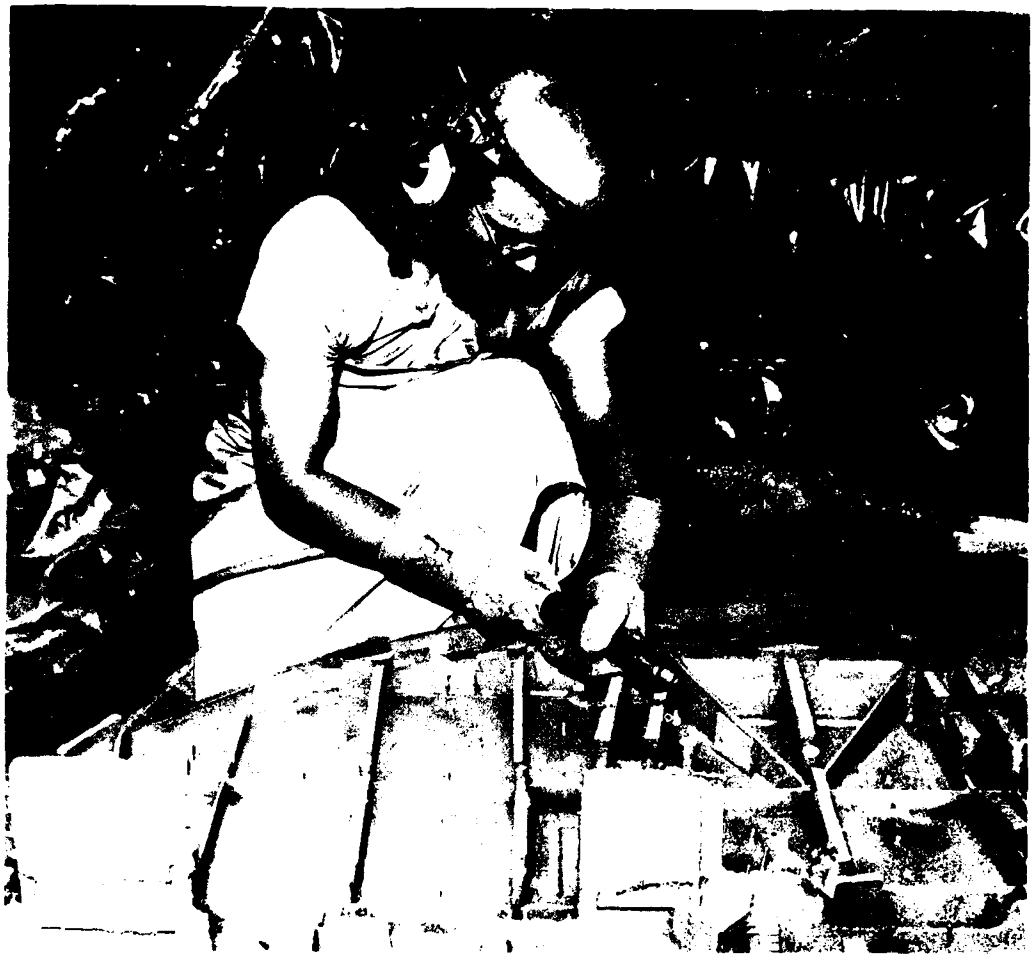


Figure 44 Finish Grinding Excess Metal from the Bulkhead Casting

Table 1. Foundry Data Summary--Boeing-Produced Bulkhead Castings

Casting No.	Melt No.	Cu	Si	Fe	Mn	Zn	Mg	Ti	Be	Pouring: Date	Pouring: Temp. (°F)	Pouring: Time (sec.)	Inspection Remarks
	Ladle Chemistry (%)												
	Specified:	0.20 max.	6.5-7.5	0.10 max.	0.10 max.	0.10 max.	0.55-0.65	0.10-0.20	0.04-0.07				
M01	-- --	0.009 0.001	6.6 6.7	0.07 0.07	0.001 0.001	0.005 0.005	0.65 0.66*	0.11 0.11	0.064 0.061	2-1-78	1445	75+	Numerous misruns in corrugations.
M02	A80174 A80175	0.001 0.001	6.6 6.5	0.07 0.06	0.001 0.001	0.005 0.005	0.66* 0.66*	0.11 0.11	0.054 0.062	2-10-78	1450	75+	Misruns in corrugations, lower webs, and periphery. Major shrinkage at WL 130 deck.
M03	A80238 A80239	0.005 0.005	6.7 6.7	0.07 0.07	0.001 0.001	0.005 0.005	0.72* 0.72*	0.11 0.11	0.065 0.076	2-21-78	1450	75+	Misruns in corrugations. Some shrinkage at WL 130 deck.
M04	A80293 A80294	0.001 0.001	6.5 6.6	0.09 0.09	0.001 0.001	0.005 0.005	0.64 0.67*	0.11 0.11	0.066 0.063	3-3-78	1440	75+	Minor misruns in corrugations, WL 150 tabs, and one web at lower right hand side. Some shrinkage at WL 130 deck.
M05	A80358 A80359	0.001 0.001	7.0 6.9	0.11 0.09	0.002 0.002	0.005 0.005	0.63 0.72*	0.12 0.12	0.061 0.069	3-20-78	1430	75+	Very minor misruns in webs and one corrugation. Minor shrinkage at WL 130 deck.
M06	A80408 A80409	0.002 0.001	6.9 7.3	0.08 0.09	0.001 0.001	0.005 0.005	0.64 0.60	0.11 0.12	0.056 0.057	3-31-78	1440	72+	Nonfill area at lower corner of casting.
M07	A80527 A80528	0.001 0.001	7.2 7.2	0.09 0.09	0.001 0.001	0.001 0.001	0.68* 0.68*	0.12 0.12	0.067 0.072*	4-25-78	1445	76+	2 misruns approx. 2 x 3 in. in corrugations at WL 135. 4 minor misruns in webs.
M08	A80666 A80667	0.001 0.003	7.0 7.0	0.09 0.10	0.001 0.002	0.001 0.001	0.67* 0.68*	0.12 0.11	0.061 0.056	5-23-78	1440	75+	Very minor misruns, 3 areas in corrugations.
M09	A80753 A80754	0.001 0.001	6.9 7.2	0.08 0.08	0.001 0.001	0.005 0.005	0.67* 0.69*	0.13 0.12	0.040 0.053	6-8-78	1440	75+	Minor misruns in corrugated sections and lower web.
M10	A80809 A80810	0.002 0.002	6.8 6.8	0.09 0.09	0.001 0.001	0.005 0.005	0.69* 0.68*	0.12 0.12	0.048 0.020	6-19-78	1445	72+	Minor misruns in web sections and one in *the corrugated section.*

*Outside specification limits. Acceptable to Engineering.

F. WELD CORRECTION

1. Defect Identification

Casting defects such as cracks, shrinkage, porosity, and misruns were corrected on bulkhead castings M04 and M07 according to procedures described in preliminary specification W-XXXX, Welding, Fusion, Correction of Primary Structural A357 Aluminum Alloy Castings (Appendix E). Defects were identified visually and by radiographic and penetrant inspection techniques. All weld correction was performed prior to heat-treat operations.

Areas of weld correction for bulkhead casting M04 are shown in Figure 45. The decision on whether or not to weld-correct specific defects on the casting was dependent upon the severity of the defect, its location relative to critically stressed areas of the casting, its nature (shrinkage, porosity, or crack), and its relative size. Weld-corrected areas on casting M07 are shown in Figure 46.

All internal defects that were subjected to weld correction procedures were ground out and prepared according to procedures outlined in Section 3.12 of the Manufacturing Plan (Appendix A). Figure 47 shows a typical crack defect in a bulkhead casting being prepared for weld correction.

2. Welding Procedure

All weld correction was accomplished by Gas Tungsten Arc Welding (GTAW) in the alternating current (AC) or direct current (DC) mode or by the Gas Metal Arc Welding (GMAW) process. The process selection was dependent upon such factors as material thickness, available welding equipment, and availability of suitable weld filler material. Figure 48 shows weld correction being performed by the GTAW process on the aft side of the M04 bulkhead casting, and Figure 49 shows the forward side during weld correction.

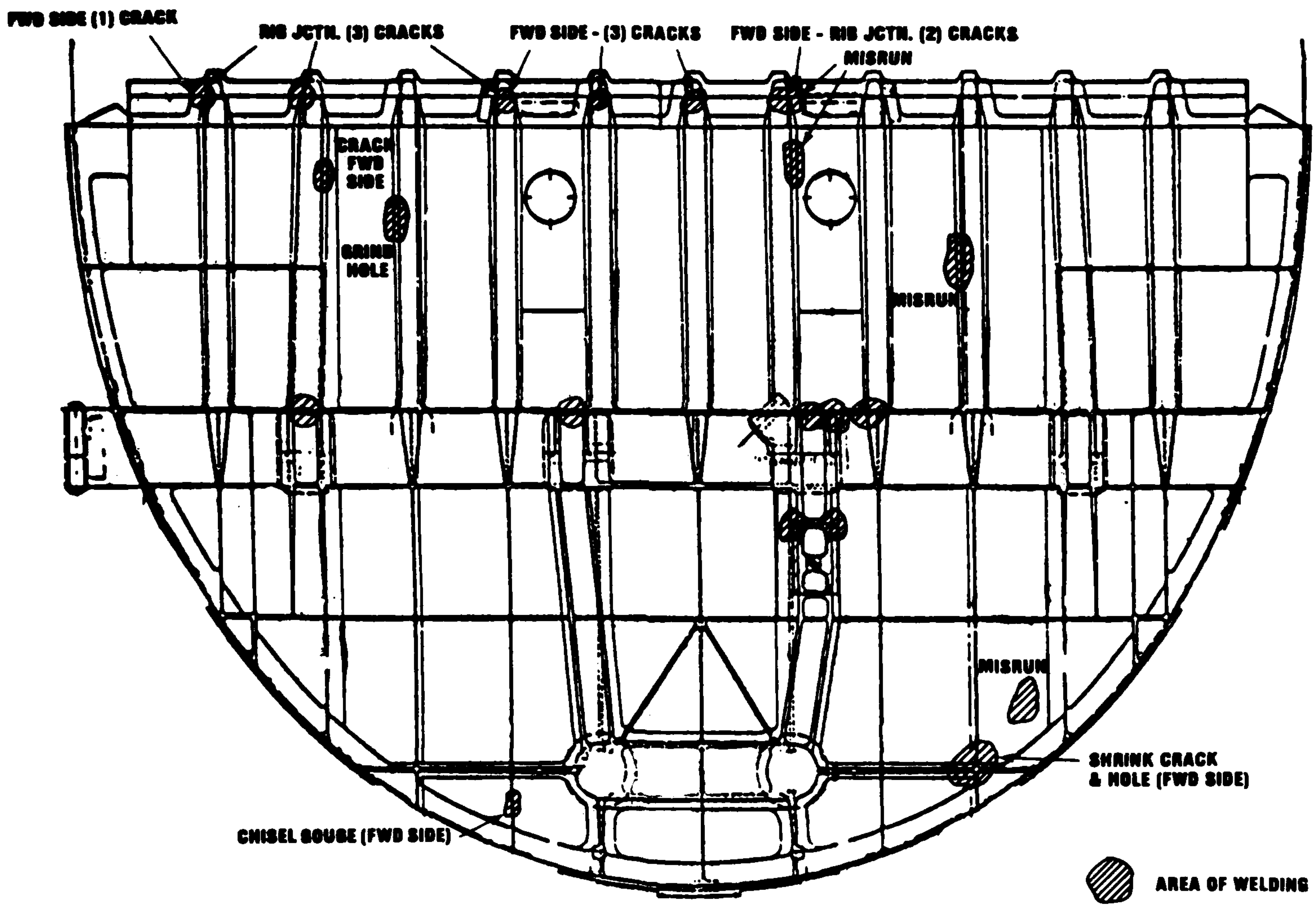


Figure 45 Weld Correction Locations - Bulkhead Casting M04

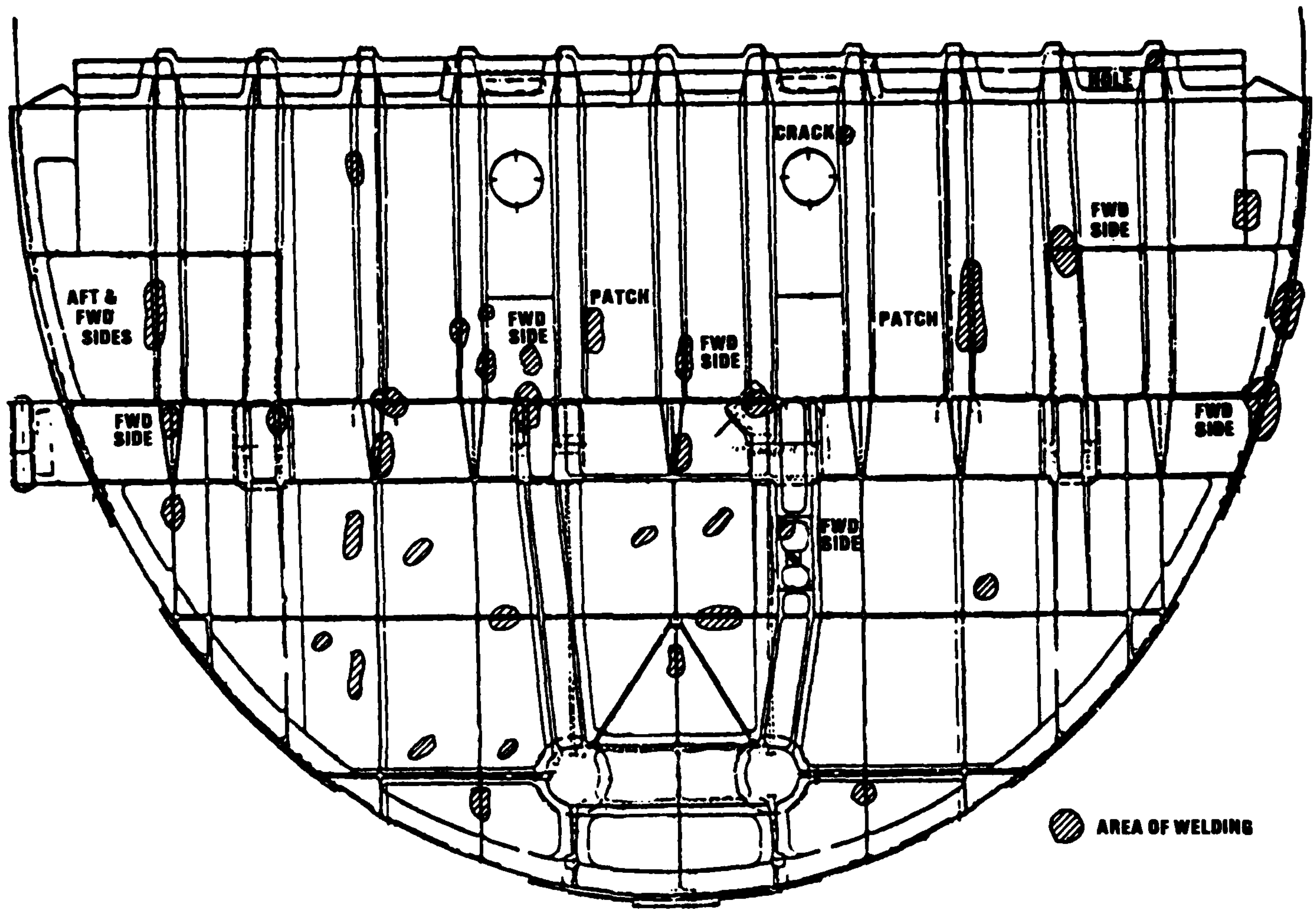


Figure 46 Weld Correction Locations - Bulkhead Casting M07

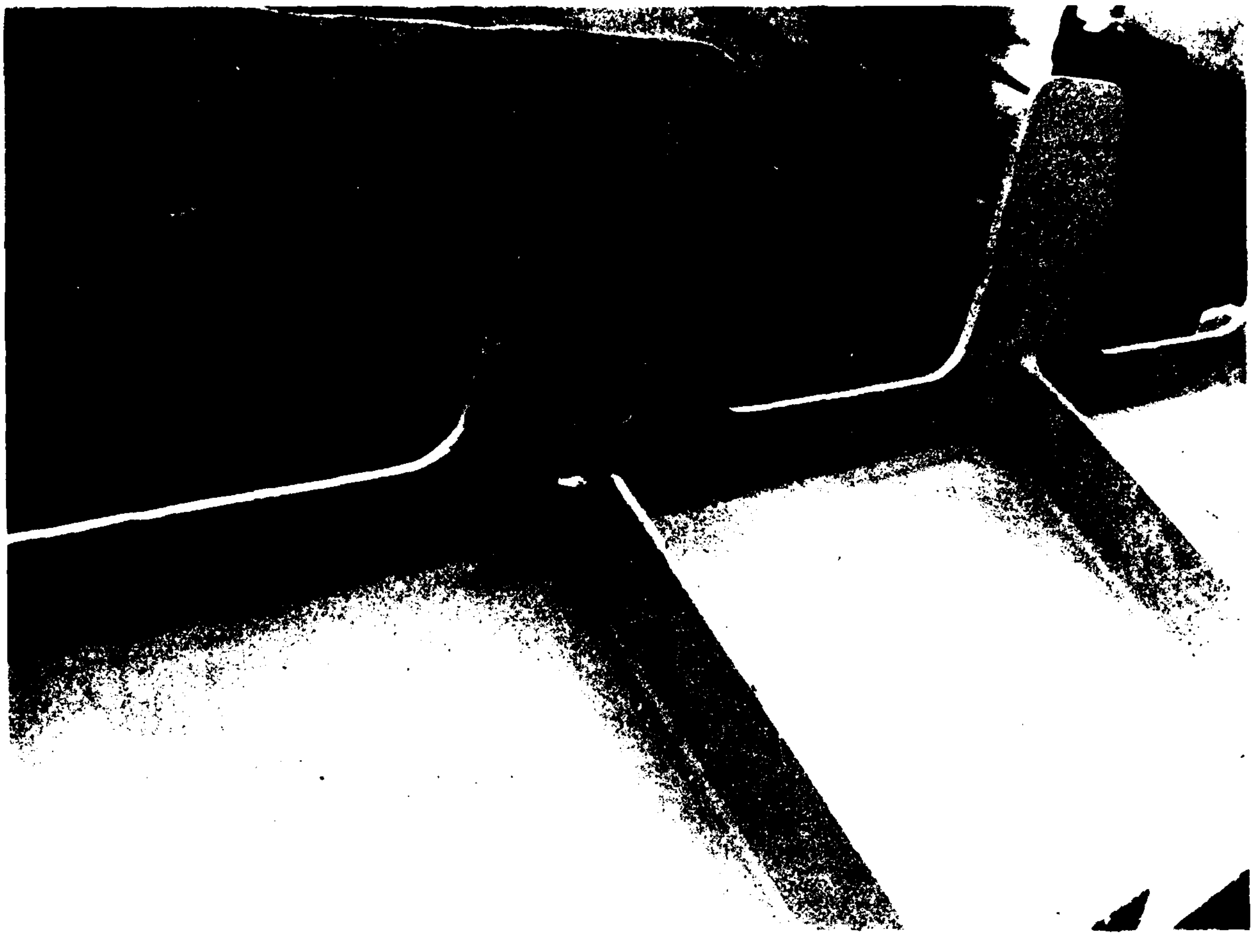


Figure 47 Crack Defect on a Bulkhead Casting Ready for Weld Correction

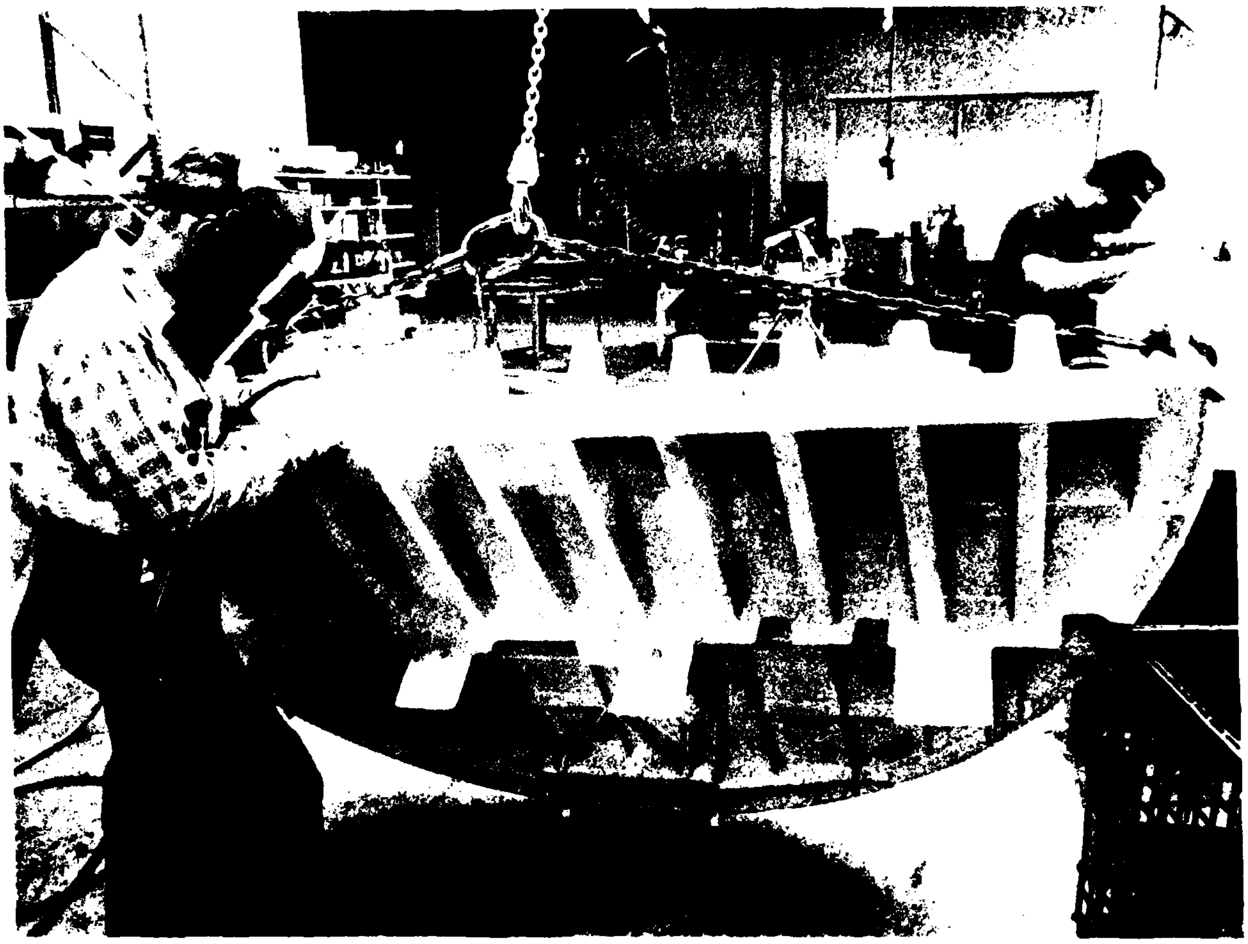


Figure 48 Weld Correction - Aft Side View of Bulkhead Casting

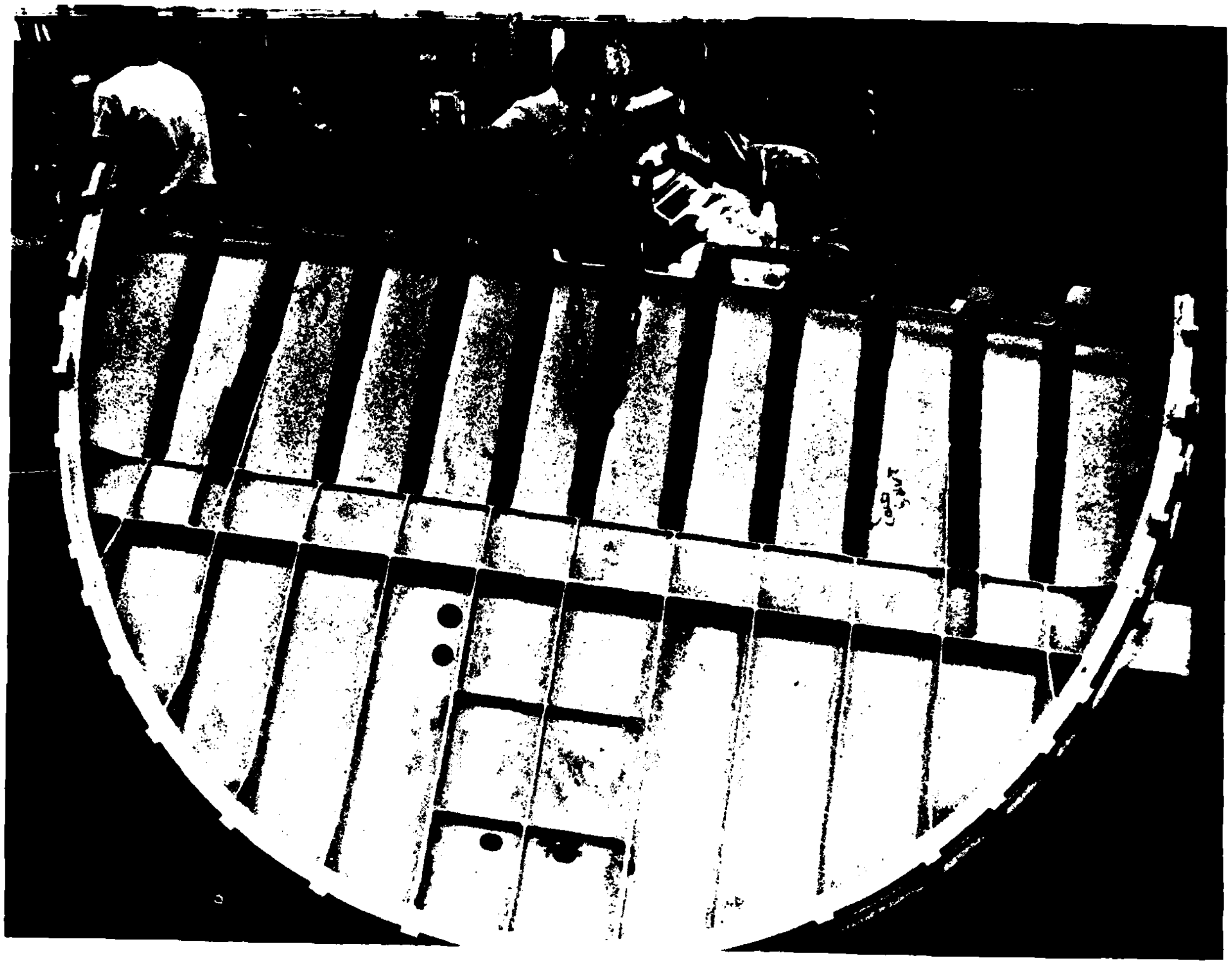


Figure 49 Weld Correction - Forward Side View of Bulkhead Casting

G. HEAT TREATMENT/STRAIGHTENING OPERATIONS

1. Heat Treat

Bulkhead castings M04 and M07 were processed through solution heat treat, quenching, and aging operations per Table IV of preliminary specification M-XXXX, Aluminum Alloy A357 Castings, Primary Aircraft Structure (Appendix D). During solution heat-treat and quenching procedures, the castings were supported by heat-treat fixture HTF 162-00017. Figure 50 shows the forward side of a bulkhead casting in the heat-treat fixture, and Figure 51 shows the aft side. Upon quenching from the $1010 \pm 10^{o}F$ solution heat-treat temperature, the castings were held in the quench tank ($160 \pm 10^{o}F$ water) for about 5-10 minutes to allow complete cooling to the temperature of the quenchant. Heat-treat operations conducted on the bulkhead castings were according to Section 3.13 of the Manufacturing Plan (Appendix A).

2. Straightening Operations

Each of the two castings mentioned displayed "oil-canning" distortion in the thin web sections after quenching. Because A357 aluminum alloy is a precipitation-hardening alloy, the bulkhead castings were immediately covered with dry ice after quenching to inhibit natural aging. The dry ice was maintained on the parts for a minimum of 30 minutes to ensure temperature equilibrium between the dry ice and the casting. After equilibrium was achieved, the dry ice was removed and the parts were mechanically straightened as required to the dimensions shown on drawing 162-00017. Due to the precipitation-hardening characteristics of the alloy at room temperature, straightening operations were limited to a total of 6 hours.

The actual amount of straightening required was much less than anticipated. Straightening was needed on several ribs, the tabs at the base of the casting, and the shelves at WL 130. In addition, some oil-canning occurred in the web areas. The time necessary to straighten each casting was 2 manhours.

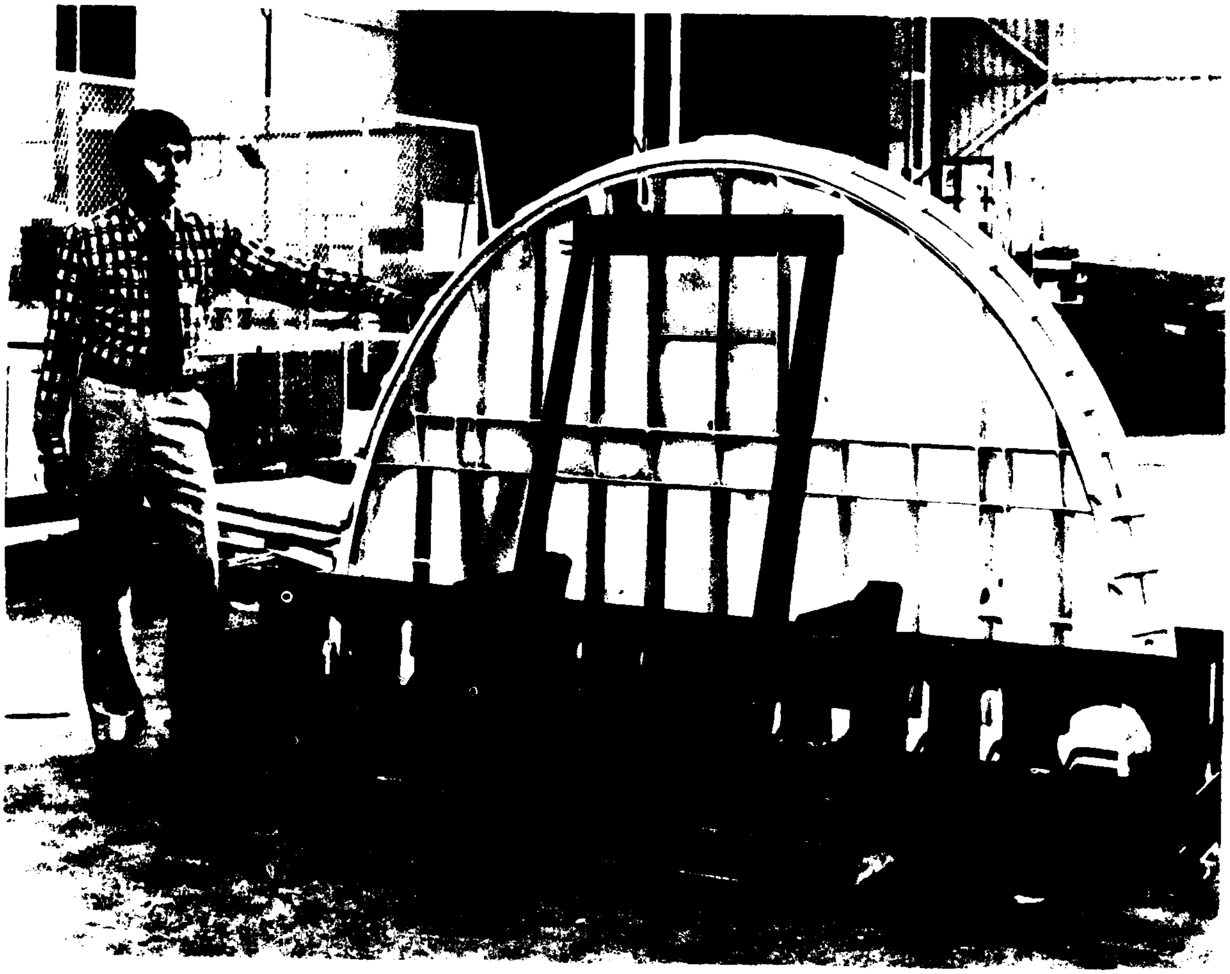


Figure 50 Heat Treat Fixture 162-00017 with Bulkhead Installed - Forward Side

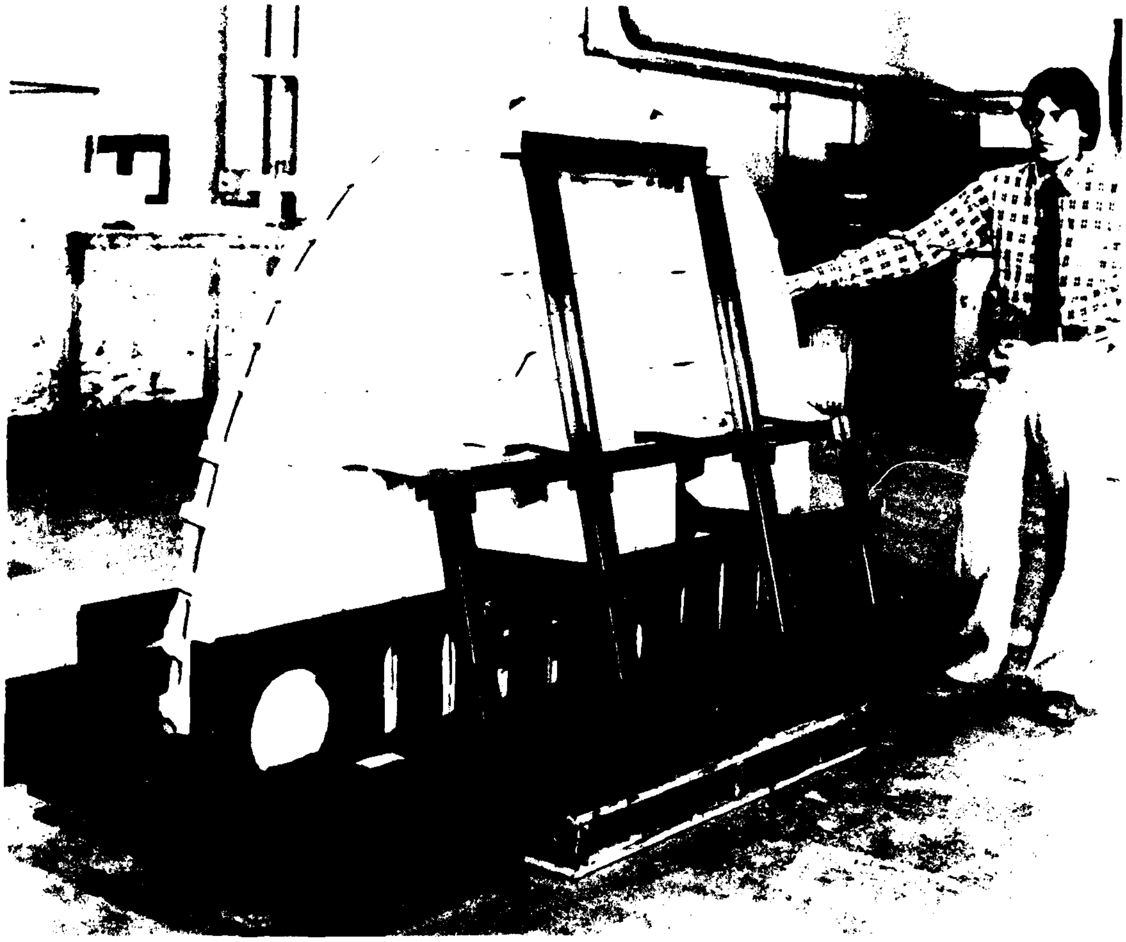


Figure 51 Heat Treat Fixture 162-00017 with Bulkhead Installed - Aft Side

H. MACHINING/CONVERSION COATING

1. Machining

Bulkhead castings M04 and M07 were completely machined per drawing 162-00018 as required (ref. 1). Each of the castings was machined on a numerically controlled (NC) milling machine with 5-axis milling capability for periphery and lug face machining operations. To inhibit movement of the part during machining and to ensure dimensional accuracy, the bulkhead castings were positioned in a machining fixture (NCMF 162-00018) during milling operations. Boring operations for the lug sections of the bulkhead castings were performed with a pneumatic portable boring assembly. Figure 52 shows a bulkhead casting in the machining fixture on the 5-axis milling machine. The machining fixture was subsequently used for inspection measurements on the finished machined surface with respect to dimensions described in drawing 162-00017 (ref. 1).

2. Conversion Coating

Casting M04 was chromic acid anodized and casting M07 was alodined as a production expedient. Upon completion of the conversion coating, bushings were placed in the lug section holes per drawing requirement.

I. CASTING WEIGHTS

Castings M04 and M07 were weighed after final machining, and the weights were recorded for comparison with sheet metal fabricated bulkhead weight. The final weight of casting M07 was 198 pounds and the final weight of M04 was 197 pounds.

The theoretical weight of the bulkhead casting is 181 pounds in the finished machined condition. The excess weight of castings M04 and M07 resulted from additions to the pattern to correct mislocated lugs and to increase thickness of the periphery wall. In a production situation, the pattern would have been reworked to correct all deficiencies without adding excess material to the casting.

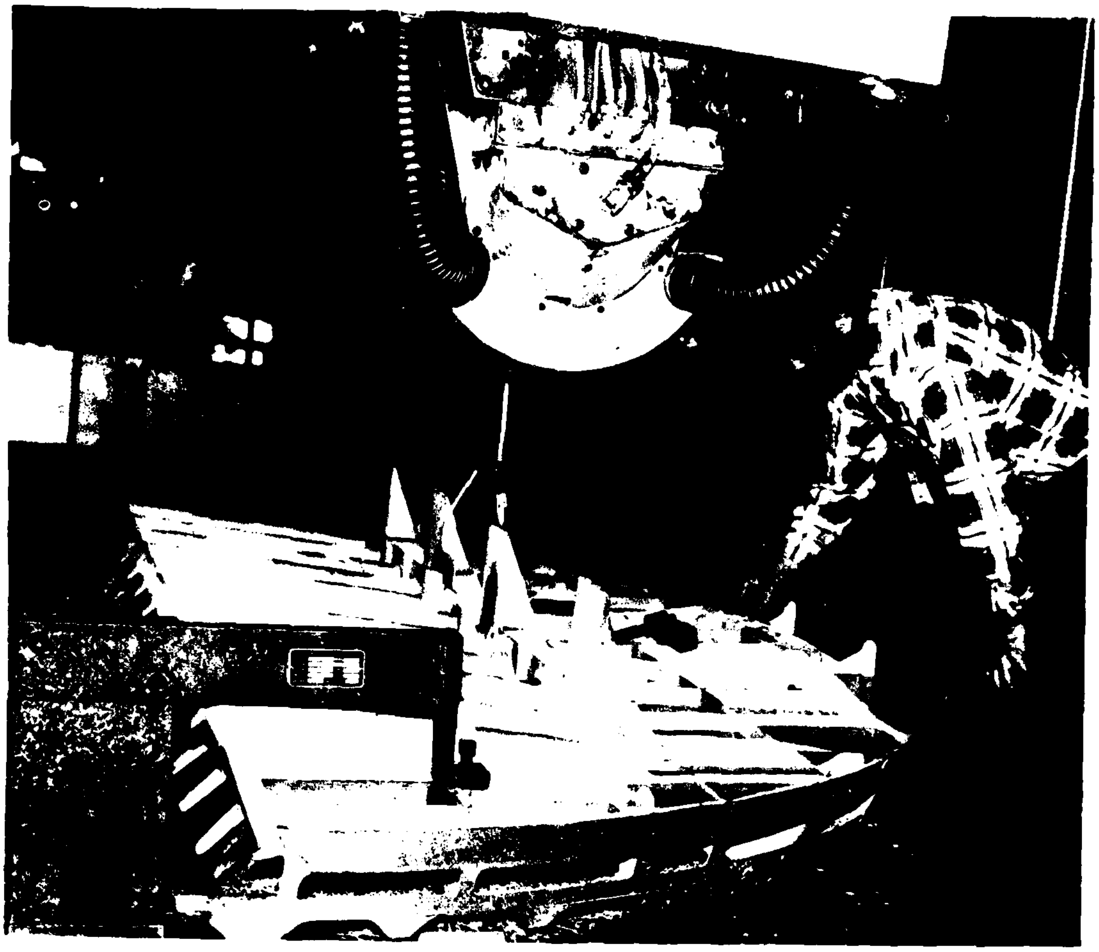


Figure 52 Machining the Bulkhead Casting in Machining Fixture 162-00018

J. FATIGUE TEST SETUP—TRANSITION STRUCTURE

In addition to full-scale fabrication of the YC-14 station 170 body/nose landing gear support bulkhead casting, Phase IV of the CAST program included construction of a transition section structure for testing of bulkhead castings under dynamic and static load conditions in simulated aircraft service. Bulkhead casting M07 was installed in the transition section for durability (fatigue) testing at the Air Force Flight Dynamics Laboratory (AFFDL), Wright-Patterson Air Force Base, Ohio. Installation of the bulkhead casting in the transition section was performed according to procedures outlined in the Developmental Test Support Order (DTSO) included in Appendix B. The procedures for removal of the bulkhead casting from the transition structure are outlined in Appendix C.

Figure 53 shows bulkhead casting M07 installed in the transition section structure.

K. QUALITY CONTROL

1. Description

This section concerns the quality control procedures for NDE (nondestructive evaluation), dimensional inspection, and mechanical property determinations. Many standard material and process control procedures also were applied throughout the production of the program castings, such as chemical analyses, visual inspections, foundry control practices, and pyrometric verifications. Where pertinent, information derived from those operations has been included in preceding sections.

Thorough inspection of castings requires that sufficient methods be applied to reliably detect both surface and subsurface discontinuities. The primary NDE methods employed were fluorescent penetrant for surface discontinuities and X-radiography for internal soundness. State-of-the-art materials and methods were evaluated during Phase II, and optimum techniques were selected for application in Phase IV. While X-ray and penetrant inspections are commonly used in the casting industry for inspection of nonferromagnetic castings, conventional radiography was judged to be

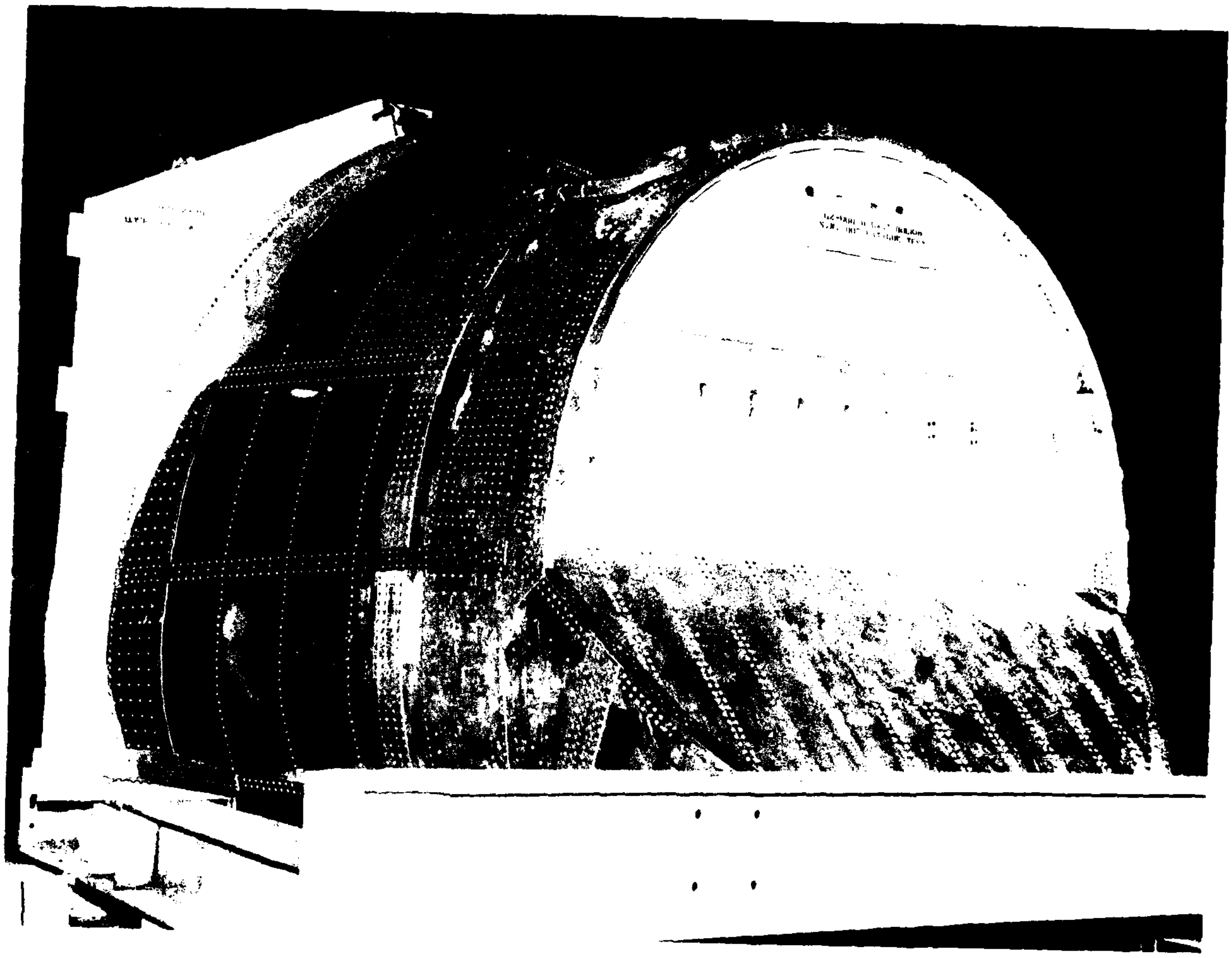


Figure 53 YC-14 Station 170 Body Bulkhead Casting M07 Installed in the Transition Section Structure

inadequate for assuring Grade B quality for fine porosity in critical, heavy sections of the bulkhead castings. Ultrasonic techniques were developed to provide additional assurance in assessing the internal soundness of these heavy sections (from 0.75 to 4 inches thick).

It also was necessary to develop suitable nondestructive methods for metallographic measurement of DAS (dendritic arm spacing) on designated surface areas of the full-size castings. This procedure provides measurements relating to effectiveness of chills and likely level of mechanical properties attained in local areas of a casting.

Dimensional inspections and mechanical property determinations were accomplished by conventional procedures.

2. X-Ray Inspection

A uniformly sound casting is critical to the achievement of consistently high mechanical properties. Radiographic inspection was the primary internal inspection method employed, and optimum techniques were derived during development of foundry control and manufacturing practices.

The casting drawing designates radiographic quality Grade B in all critical areas and Grade C in the remainder of the casting. The critical regions consist mostly of thicknesses of 0.75 to 4 inches, but the inherent limitations of radiographic inspection do not allow assessing with full confidence all unsoundness conditions in such heavy sections. This deficiency is particularly apparent when considering the sensitivity limits of the radiographic method in relation to the very small size of gas and shrinkage porosities that might be present. In essence, pores less than 0.03 to 0.04 inch in diameter are not likely to be resolved in 2-inch-thick material. Furthermore, the application of the ASTM E155-76 0.75-inch-thick comparative reference standards results in highly subjective evaluations for the greater thicknesses. However, Grade B was attained in the thickest sections of the program castings by extensive use of properly designed and placed chills. This was confirmed by supplementing radiography with ultrasonic inspection.

Radiography was accomplished with Seifert 150-kV "Isovolt" equipment having a 2.5-mm focal spot and a 40-degree-angle X-ray tube. A typical setup is shown in Figure 54. Kodak type M and GAF 400 films were used without intensifying screens. Table 2 shows typical exposure information, and Figure 55 presents view locations for the fatigue test casting (M07). Additional radiographs were made when necessary for improved resolution of questionable areas and were mandatory following weld correction operations.

Results of radiographic inspections of test castings M04 and M07 are summarized in Figures 56 and 57. All discontinuities shown were accepted upon Engineering analysis.

3. Penetrant Inspection

Based upon laboratory tests, available facilities, and practical considerations, a fluorescent penetrant inspection system was selected using a self-developing, water-washable penetrant with no developer. This system was considered to provide a sensitivity equal to Group V materials per MIL-I-25135 when used without developer. Although a specific vendor product was employed, any of a number of competitive water-washable penetrants having U.S. Air Force approval for Group VI equivalent sensitivity with developer would be satisfactory.

More important than sensitivity to penetrant inspection effectiveness and reliability of the penetrant are (1) the proper preparation of the castings prior to inspection, (2) care in inspection processing, and (3) proper evaluation of results. Sawing, grinding, and grit blasting, extensively used in cleanup of castings, are operations known to exert a smearing action that can completely close tight defects to the entry of the most sensitive penetrants. To avoid this adverse effect, a requirement was imposed on the program castings that 0.0002 to 0.0004 inch of material be chemically removed from all surfaces after cleanup. Additionally, chemical etching was required following local grinding of welds prior to penetrant inspection.

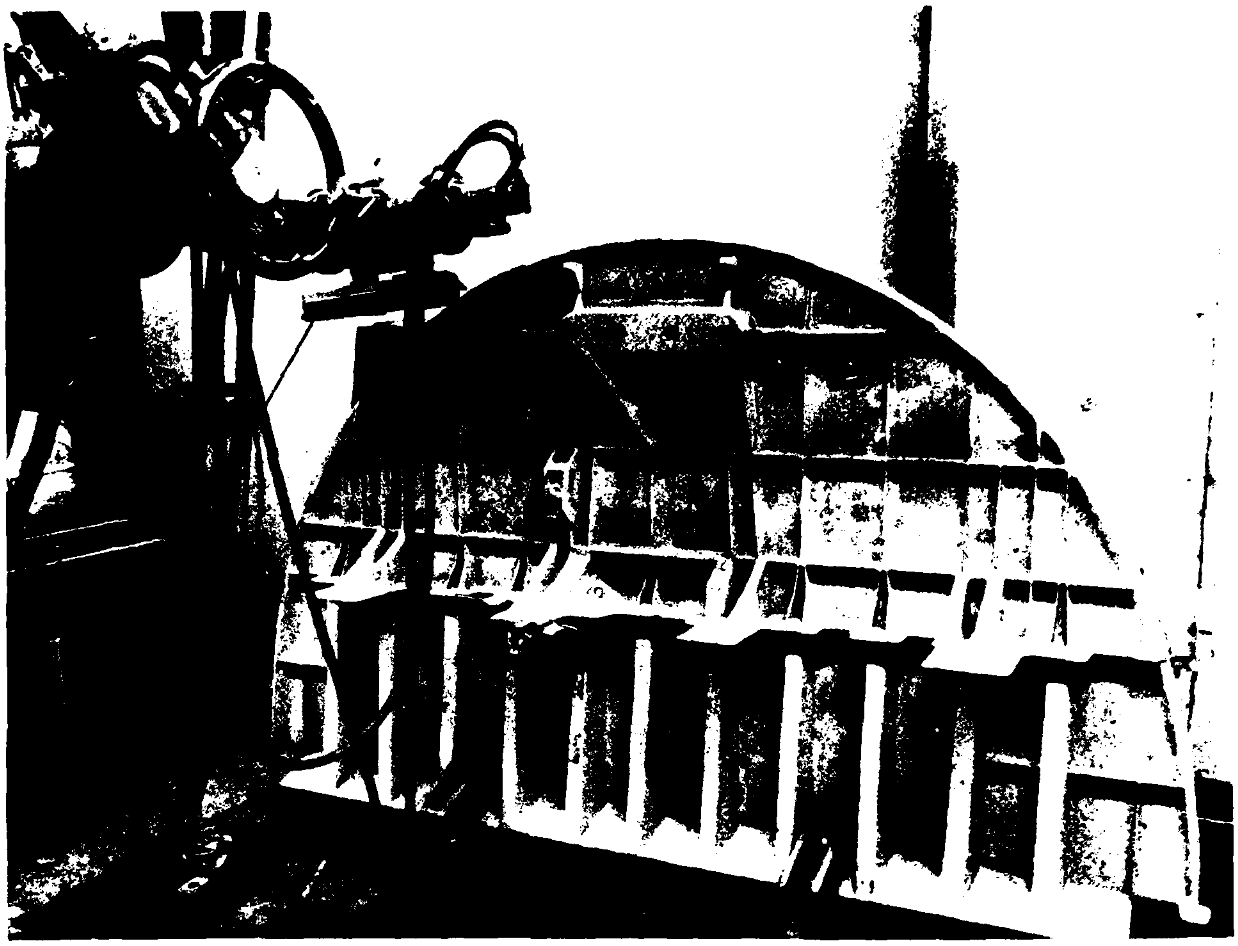


Figure 54 Setup for Radiography of Deck Flange WL 130

Table 2. Typical X-Ray Exposures

Kilovolts	37	40	42	52	65	84	90	100
Milliamperes	10	10	10	10	10	10	10	10
Time (minutes)	1	1	1	1	1	1	1	1
Film, Focal Distance (inches)	36	32	36	36	36	36	36	36
Thickness, Nominal (inches)	0.10	0.10-0.14	0.12	0.50	0.75	0.50	0.60	2
Angle (degrees)	90	30	12	70	70	40	12	70

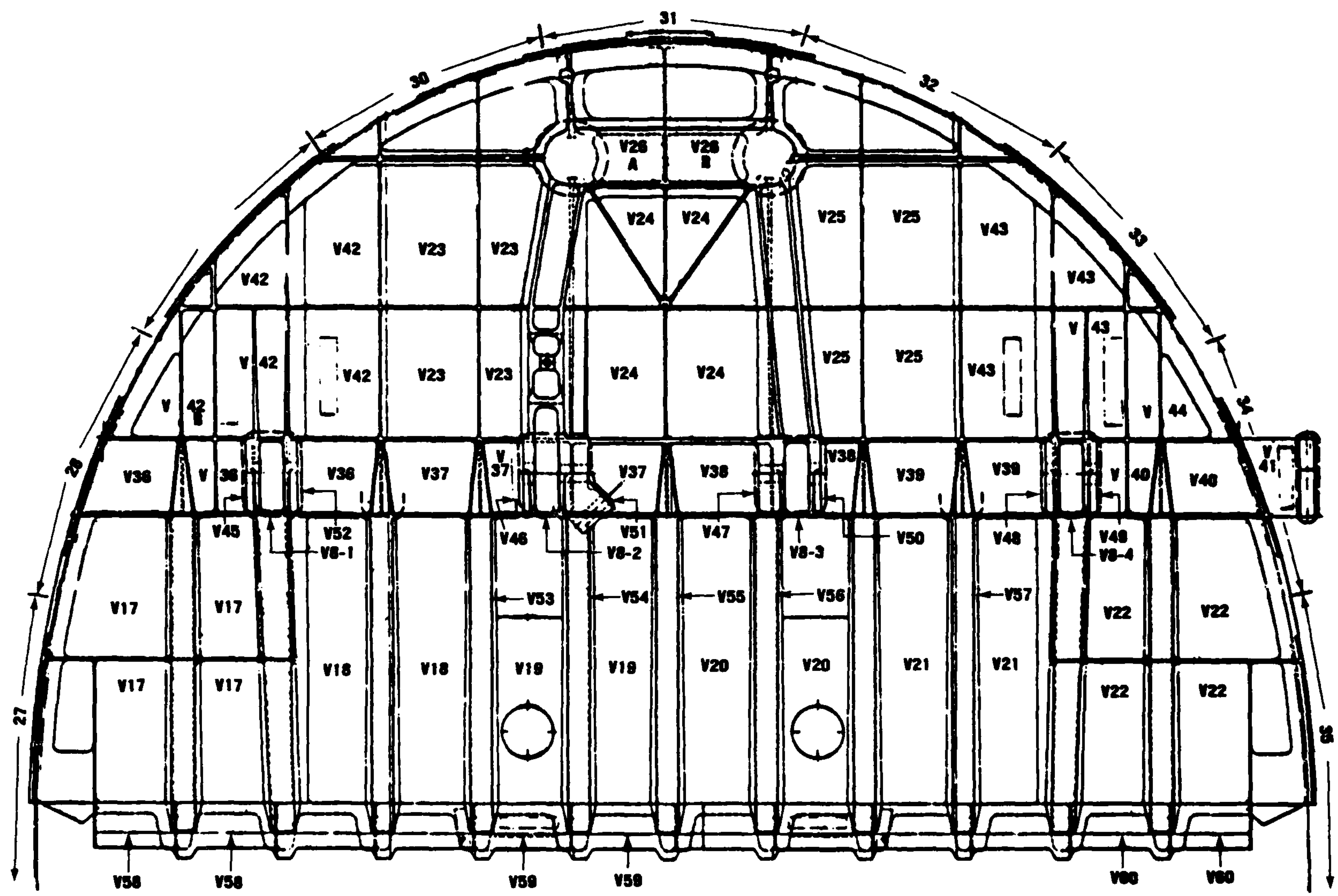


Figure 55 Radiographic View Locations for Bulkhead Casting (M07)

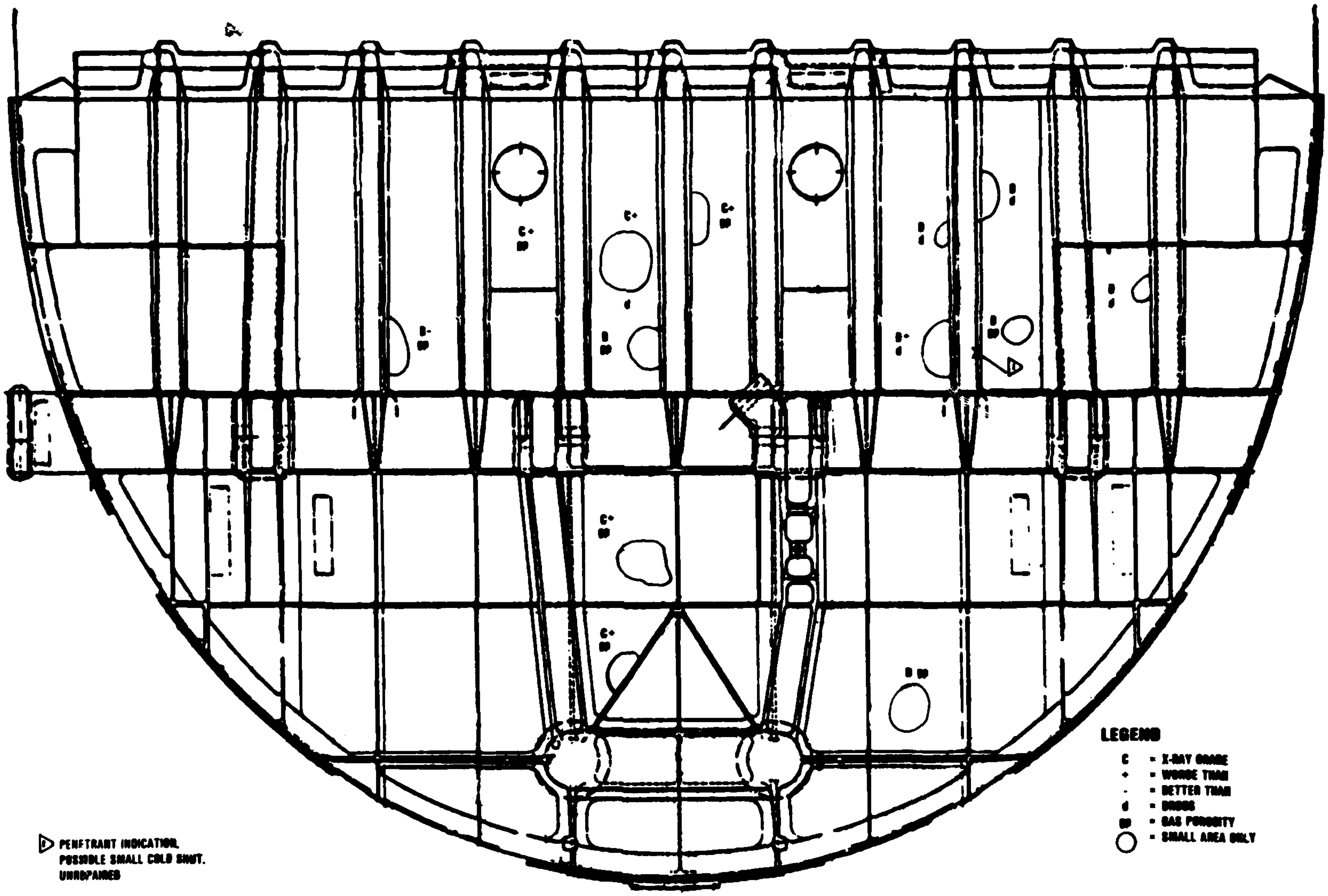


Figure 56 Radiographic and Penetrant Inspection Results - Bulkhead Casting M04

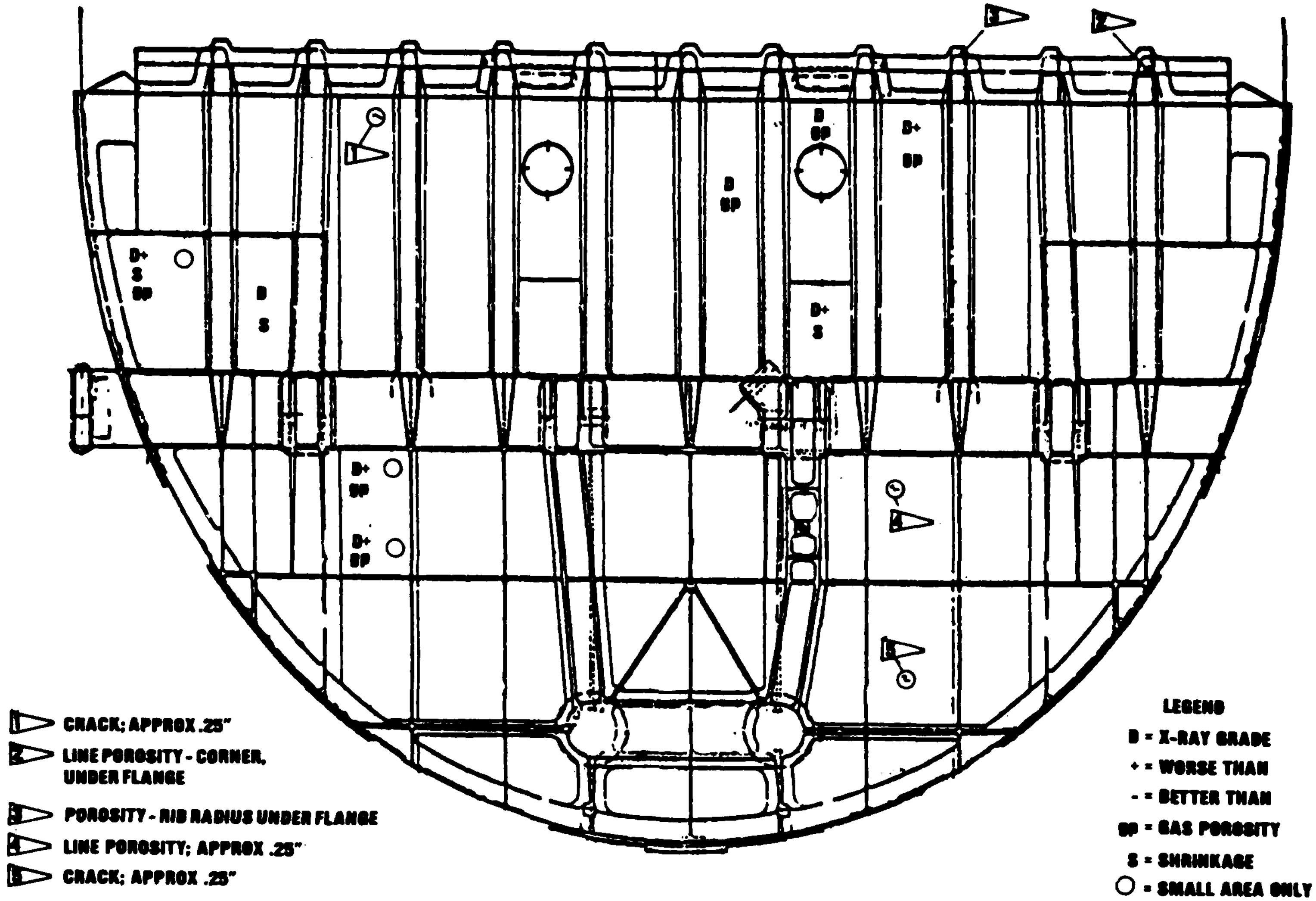


Figure 57 Radiographic and Penetrant Inspection Results - Bulkhead Casting M07

Penetrant inspections were performed at several stages of the manufacturing operations. The first inspection was performed after cleanup, X-ray inspection, and initial weld corrections. Any additional weld correction areas were locally reinspected. Full penetrant inspection was again accomplished following heat treatment and straightening. Final inspection then was performed on the finish machined castings prior to protective finishing. Uncorrected discontinuities revealed by penetrant inspection are also indicated in Figures 56 and 57 together with X-ray results.

4. DAS (Dendritic Arm Spacing)

The relationship of dendritic arm spacing to mechanical strength and ductility has been recognized for some time. The dendritic structure must be very fine in order to achieve superior properties. This feature of the cast microstructure is controlled by solidification rate, as determined by gating, chilling, and other foundry practices. Therefore, DAS measurements can greatly assist the development of necessary foundry control procedures. Considerable cost savings also can be realized if these measurements can be obtained nondestructively on production castings while still in the as-cast condition before expensive cleanup, inspection, heat-treat, and other operations.

Microstructural examinations commonly are performed on specimens cut from casting sections and prepared in a metallurgical laboratory. It was necessary, therefore, to develop suitable portable metallographic methods for the microscopic measurement of DAS directly on designated surface areas of the full-size bulkhead castings.

A mechanical approach to metallographic preparation of local areas of a casting surface was developed, and the resulting technique proved to be simple and rapid. A flexible-shaft motor tool was used for rough and fine grinding, using three grades of rubber-bonded abrasive wheels. Polishing was accomplished with the same tool, using cotton laps charged with 6- and 1/2-micron diamond pastes, as shown in Figure 58. After polishing, the surface was etched with 0.5% HF solution. At this point, direct examination with a portable microscope may be performed. However, it was

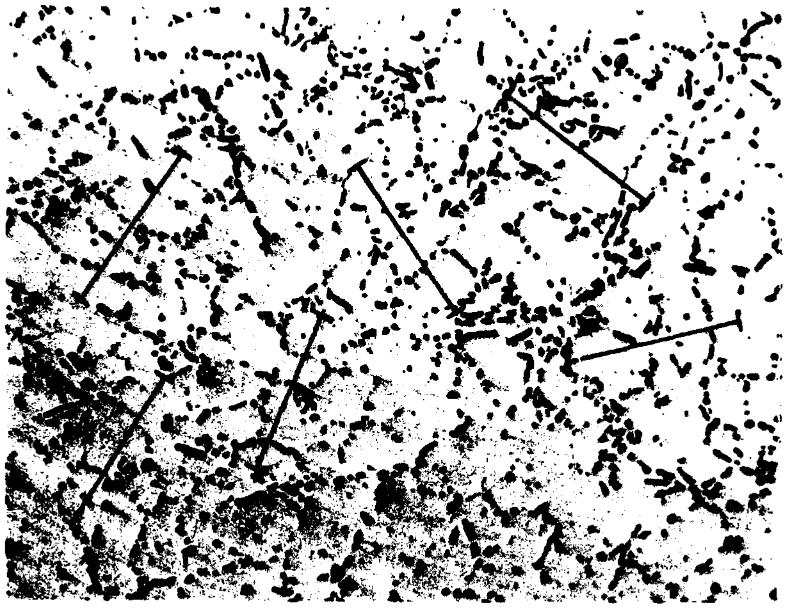
Figure 58 Polishing Steps in Metallographic Preparation of DAS Location on Full Size Casting

found to be easier to prepare a plastic replica of the etched surface, which could be better examined in the laboratory. Also, the replica may be retained as a permanent record. Figure 59 illustrates a typical cast microstructure obtained by the replication procedure and the method of deriving DAS data.

DAS determinations were made on the full-size Boeing castings at 21 locations as shown in Figure 60. Each determination represents an average value of three or more measurements. The results are presented in Table 3.

5. Ultrasonic Inspection

Ultrasonic techniques were investigated to supplement required radiography by providing improved detection of dispersed small gas or shrinkage porosities in casting sections up to 4 inches thick. Of the several approaches examined, the pulse-echo, direct porosity detection method gave the best results. Comparative reference standards were created from cast material that had 0.75-inch-thick samples removed and radiographed to establish the radiographic quality grade. It was found that due to differences in pore sizes, shapes, and distribution that can exist within material of a particular quality grade, the oscillograph display of the ultrasonic signal response can vary considerably with small displacement of the transducer. The inspector, therefore, must make a subjective judgment of the "average" ultrasonic responses when comparing oscilloscope patterns obtained from the reference standard and the casting. This can be substantially improved by using a storage oscilloscope upon which can be displayed superimposed patterns obtained from a series of closely adjacent transducer positions. Typical displays of this type are shown in Figure 61, representing relatively sound material in the top pattern (equivalent to radiographic Grade B) and less sound material at the bottom (between B and C). This technique was used in inspecting all sections of the castings greater than 0.75 inch thick. All of these areas met the Grade B requirements, and proper placement of gates, risers, and chills for development of sound material was confirmed.



$$\text{DAS} = \frac{\text{LENGTH OF INTERCEPT LINE (1")}}{\text{NO. OF INTERCEPTING SECONDARY DENDRITE ARMS}} \times \frac{1}{\text{MAG (100)}} = .0021 \text{ (AVERAGE)}$$

Figure 59 Typical Cast Microstructure and Method of DAS Determination

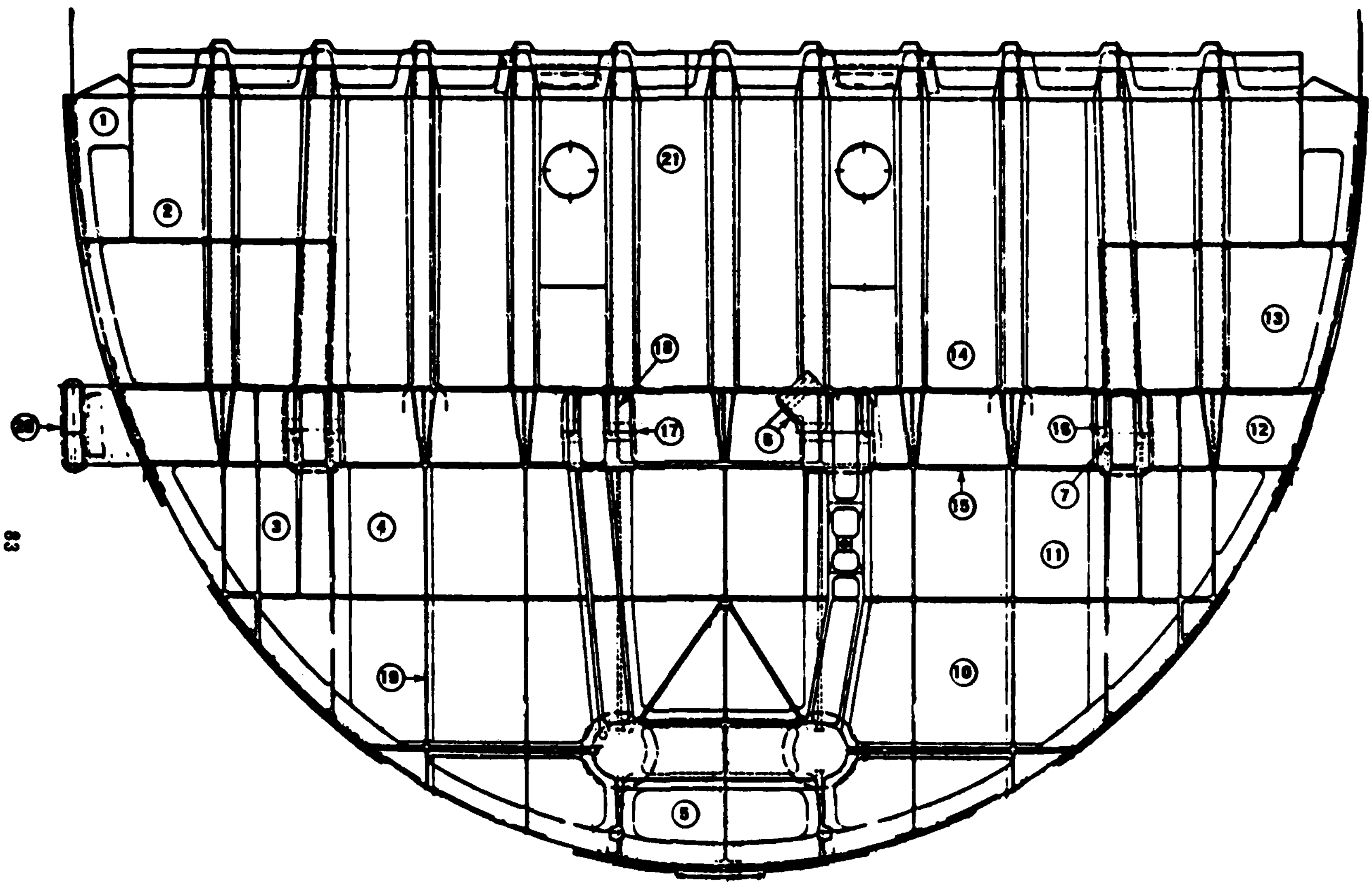


Figure 60 Dendritic Arm Spacing (DAS) Measurement Locations

AD-A078 854 BOEING AEROSPACE CO SEATTLE WA F/G 11/6
CAST ALUMINUM STRUCTURES TECHNOLOGY (CAST). PHASE IV. FABRICATI--ETC(U)
MAR 79 R C MCFIELD, L A LOGAN, J W FABER F33615-76-C-3111
UNCLASSIFIED D180-24610-1 AFFDL-TR-79-3029 NL

2 OF 4
AD A078854

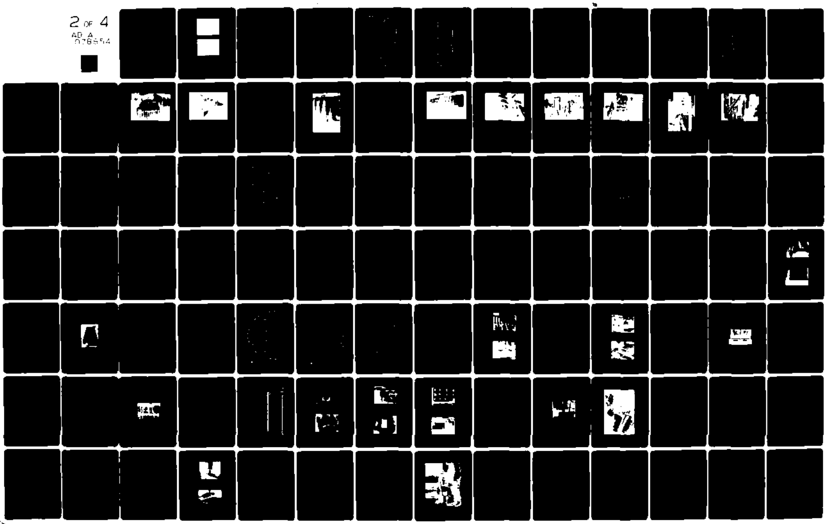
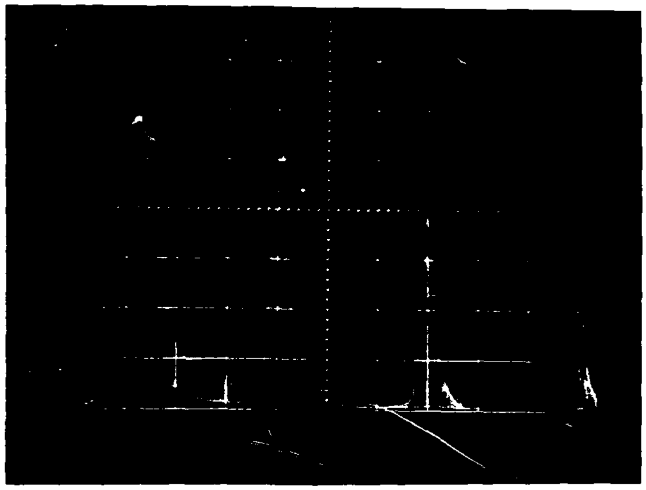


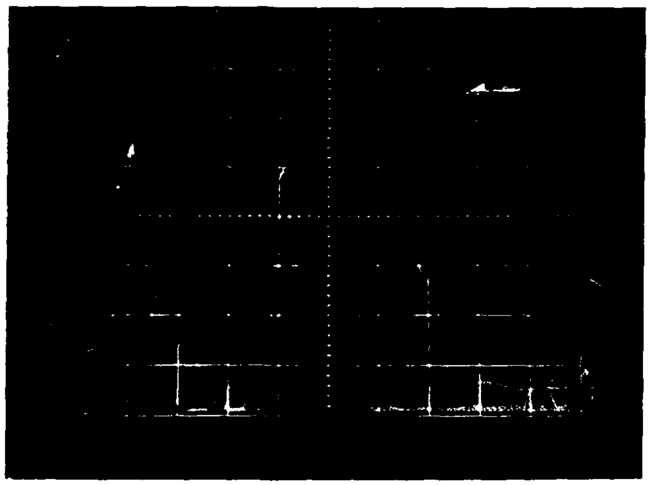
Table 3. DAS Measurements 1/

Test Location	DAS Values (0.0001 inch) for Castings				
	M02	M03	M04	M05	M07
1	16	13	16	16	17
2	13	13	14	14	9
3	13	14	13	14	11
4	13	14	17	12	10
5	10	11	8	9	12
6	5	6	11	13	8
7	7	8	8	11	8
8	21	18	17	28	14
9	5	8	10	10	7
10	11	11	10	14	10
11	12	11	12	12	10
12	12	12	14	12	11
13	11	12	11	8	11
14	9	10	10	11	7
15	11	10	7	11	7
16	7	8	6	9	8
17	5	6	8	10	8
18	6	6	7	11	8
19	20	21	28	24	21
20	21	13	--	12	15
21	13	12	12	14	11

1/ DAS measurements made to date. Additional measurements will be made on other selected castings.



NO. 3 10μ H_2 X .5 IN.



NO. 8 NORTEC 10μ H_2 X .5 IN.

Figure 61 Oscillograph Patterns of Ultrasonic Pulse-echo Signals from Cast Materials Containing Different Levels of Porosity

6. Dimensional Inspection

The trimmed and cleaned castings were fit-checked against the dimensional check fixture NCMF 162-00018. The first casting (tool-tryout casting) was extensively inspected with the fixture and an NC bridge mill having 3-axis digital readout to four decimals. As a result of this inspection, the casting pattern was modified in a few areas, primarily to increase the machining allowances.

The second production casting (MO2) was inspected to check the pattern changes and compliance with drawing dimensions. The casting was positioned and firmly clamped in the fixture against the stops at several tooling points. A dial indicator probe was placed in the bridge mill spindle, and the zero reference was established at a set-point hole in the fixture outside of the periphery of the casting. Results of this inspection are summarized in Figure 62. Drawing dimensions are identified as WL and RBL or LBL, and casting dimensions are simple numbers.

In addition, random thickness measurements were obtained ultrasonically with a Branson Digital Thickness Gage. The instrument was standardized directly on the casting at points accessible for measurement with a micrometer, and a calibration curve was established over the desired thickness range. After completing the thickness measurements, standardization was rechecked. The results are shown in Figure 63 with actual thickness values shown above the nominal drawing values.

Machined castings were additionally checked to the finished part drawing. These checks pertained to the location and dimensions of the slots and bolt holes at the attachment points for the nose landing gear assembly, as well as establishing the outer machined contour of the castings. As a matter of convenience, two methods were employed to check the contour. The fatigue test casting (M07) periphery was determined by direct measurements from fixed reference points on the machining fixture, located 1 inch nominal from the part surface, at 11 check points. Delta values are shown in Figure 64 (delta values are nominal minus actual). Random thickness measurements for this casting are given in Figure 65.

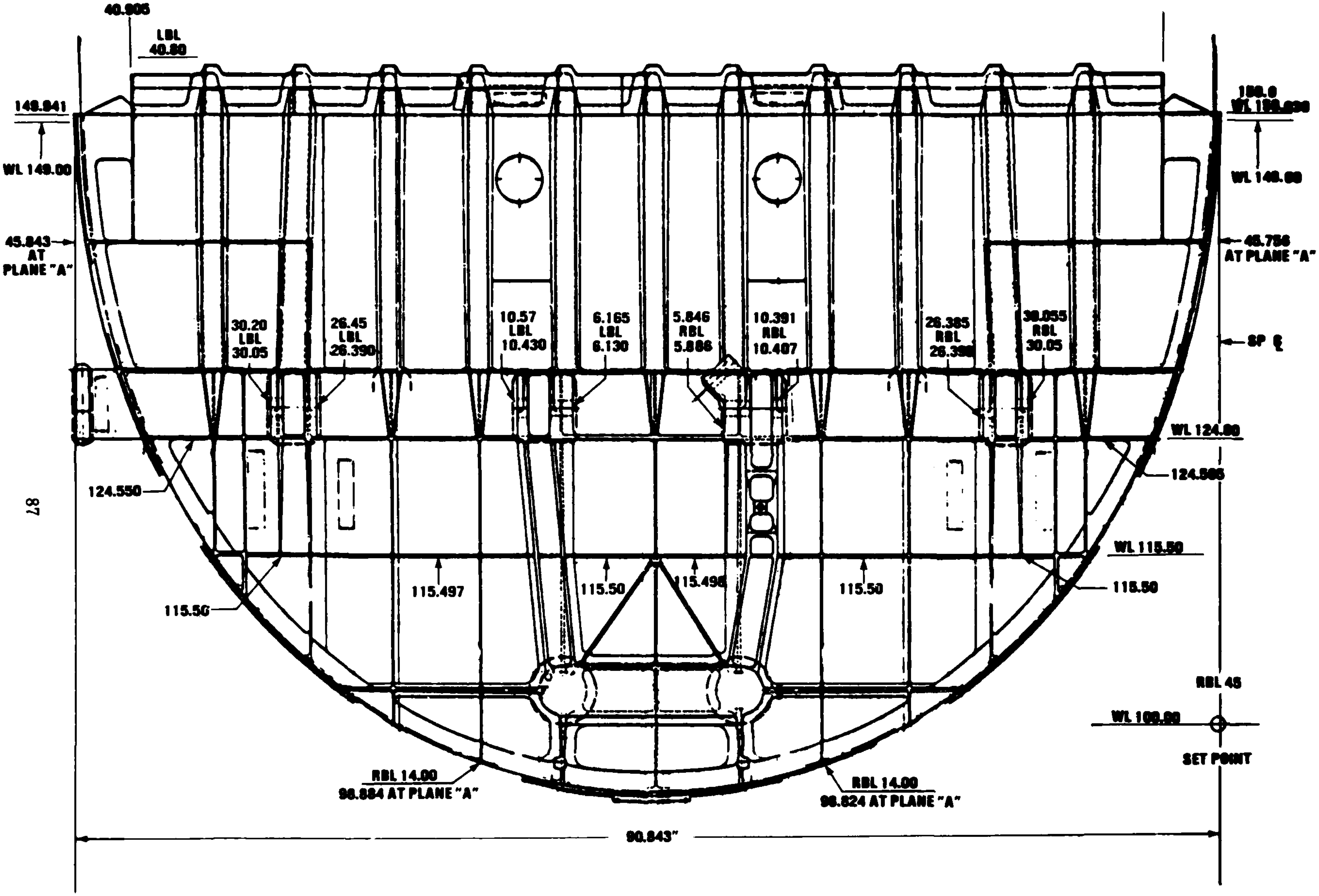


Figure 62 Dimensional Checks on Bulkhead Casting M02

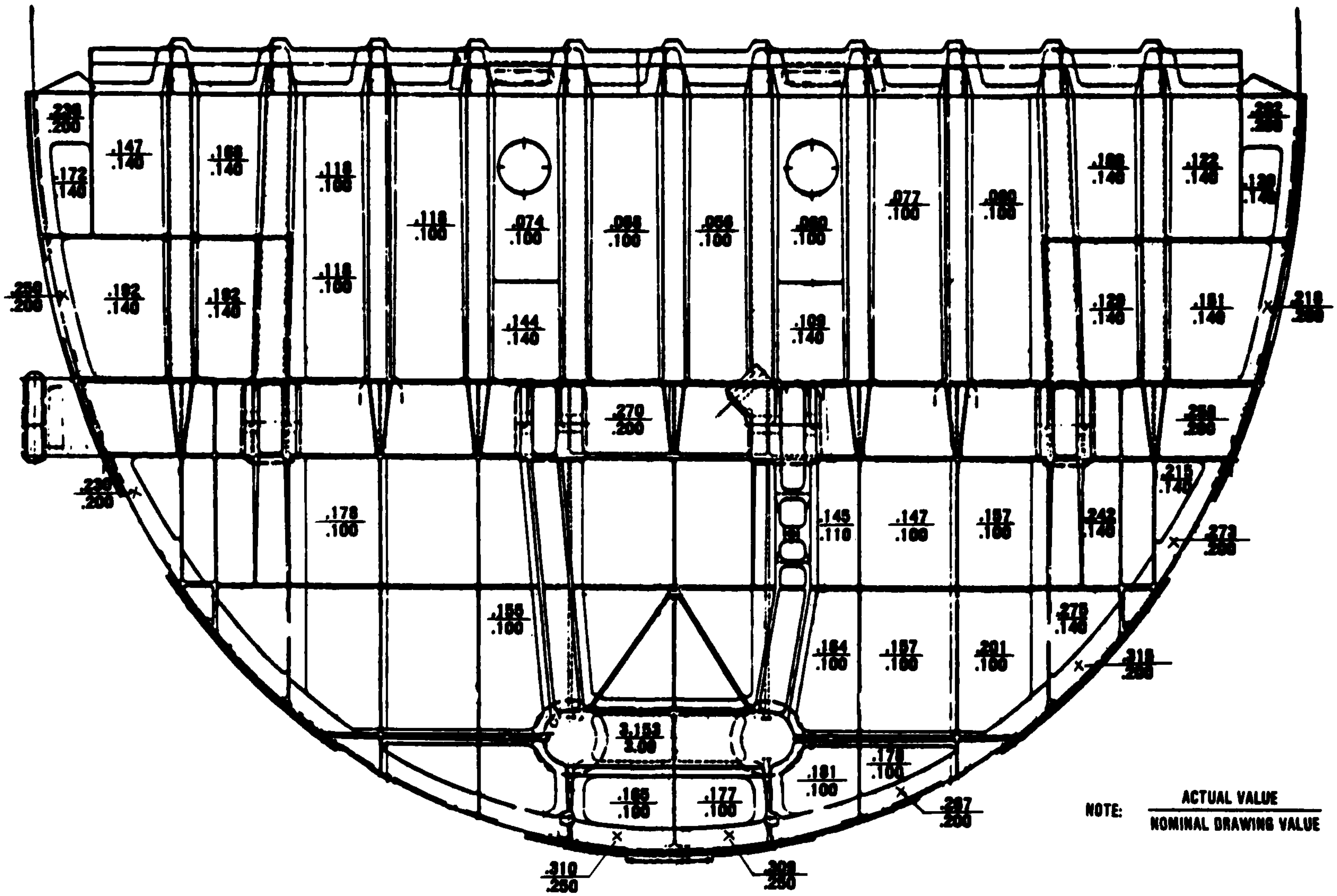


Figure 63 Thickness Measurements on Bulkhead Casting M02

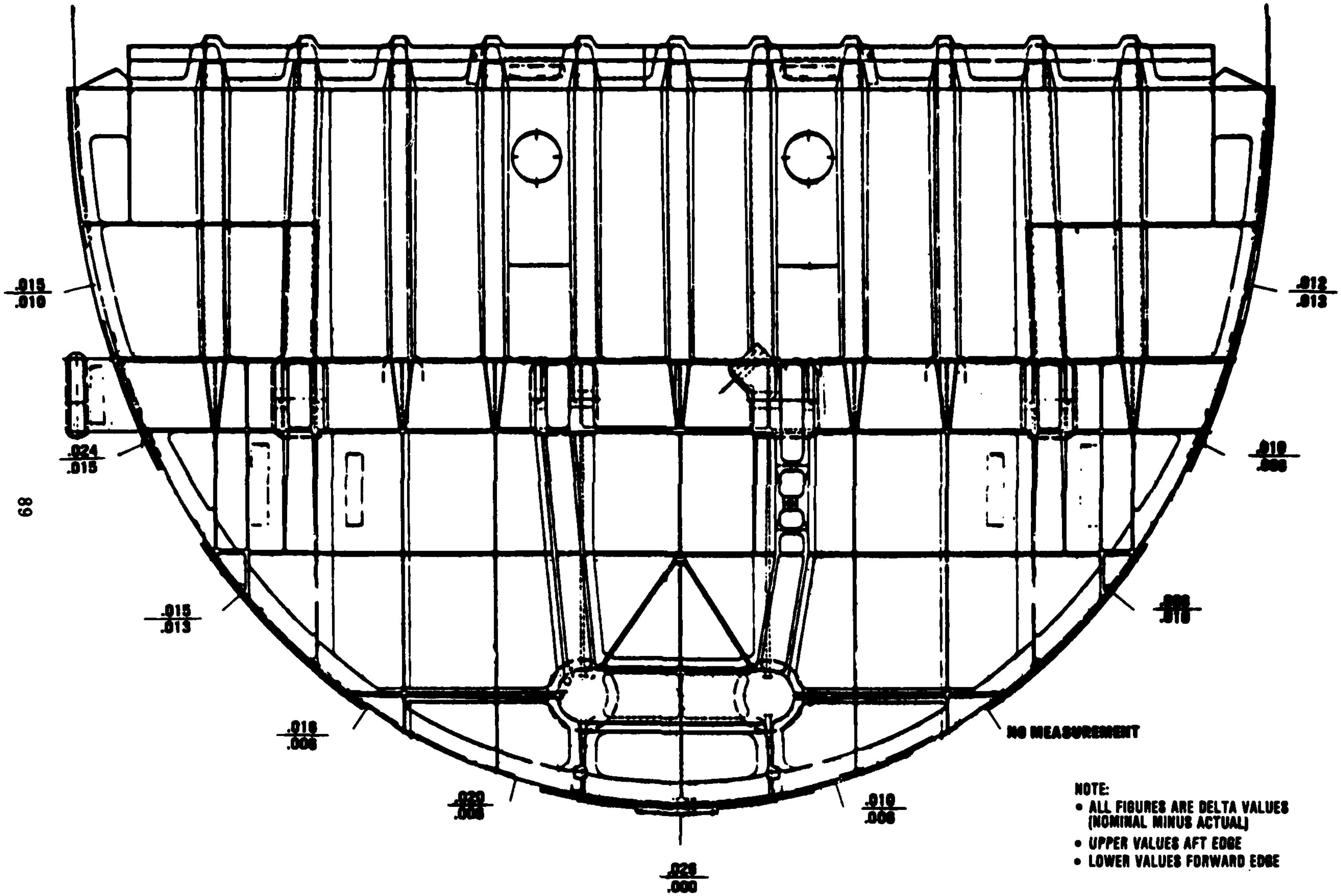


Figure 64 Outer Contour Check on Bulkhead Casting M07

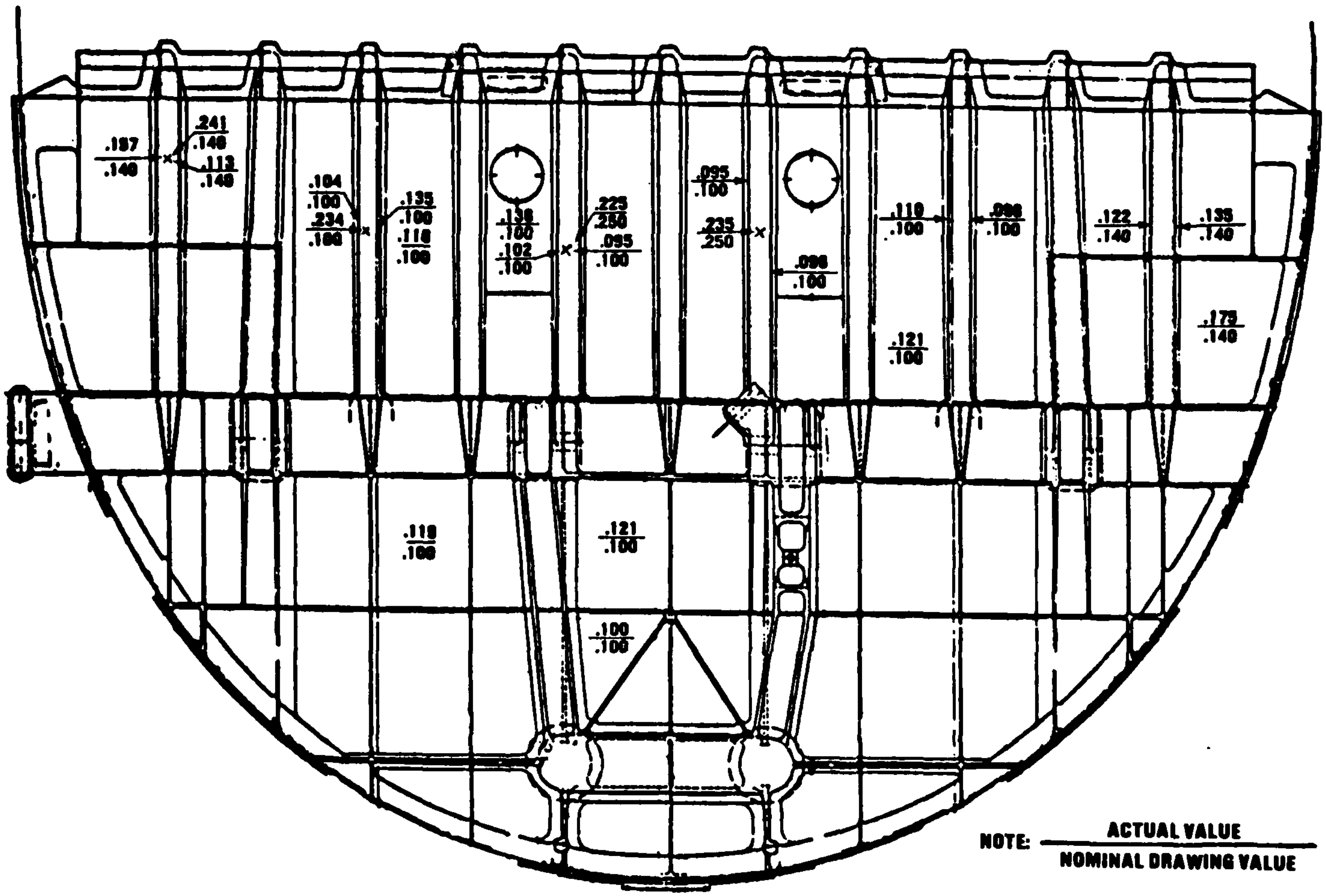


Figure 65 Random Thickness Measurements
on Bulkhead Casting M07

The contour of the static test casting (M04) was checked on the machining fixture with points located by the NC bridge mill at programmed locations following the outer contour. Check point locations are sketched in Figure 66, and the calculated and actual coordinate locations are given in Table 4. Figure 67 presents random thickness measurements obtained on this casting.

It is noted that the thickness measurements in certain web and channel areas are above the nominal drawing values. The reason for these excessive thickness indications will be investigated in detail in following work in Phase V of the program, where castings will be sectioned for nondestructive inspection cross-check.

7. Mechanical Properties

Mechanical properties obtained from integrally cast material on the static and fatigue test castings (M04 and M07 respectively) are presented in Table 5.

L. COST COMPARISON

Based upon estimates of costs for the fabrication of 300 ship-sets, an approximate cost reduction of 34.9% would result from fabricating YC-14 station 170 body/nose landing gear support bulkheads by state-of-the-art casting methods. The cost reduction figure results from differences in sheet metal buildup costs for the bulkhead configuration versus fabrication of a single monolithic cast structure.

In Phase III, "Detailed Design," activities on the CAST program, estimates were made for the sheet metal buildup configuration of the bulkhead (Report AFFDL-TR-78-7). Based upon current techniques, sheet metal buildup fabrication of 300 bulkheads would result in a total cost of $3,745,200.00. This total figure represents a unit cost of $12,484.00 per sheet metal bulkhead. In contrast, current estimates show that fabrication of the bulkheads by state-of-the-art casting methods would result in a total cost of $2,438,850.00 for 300 bulkheads. This total figure represents a unit cost of $8,129.50 per cast bulkhead.

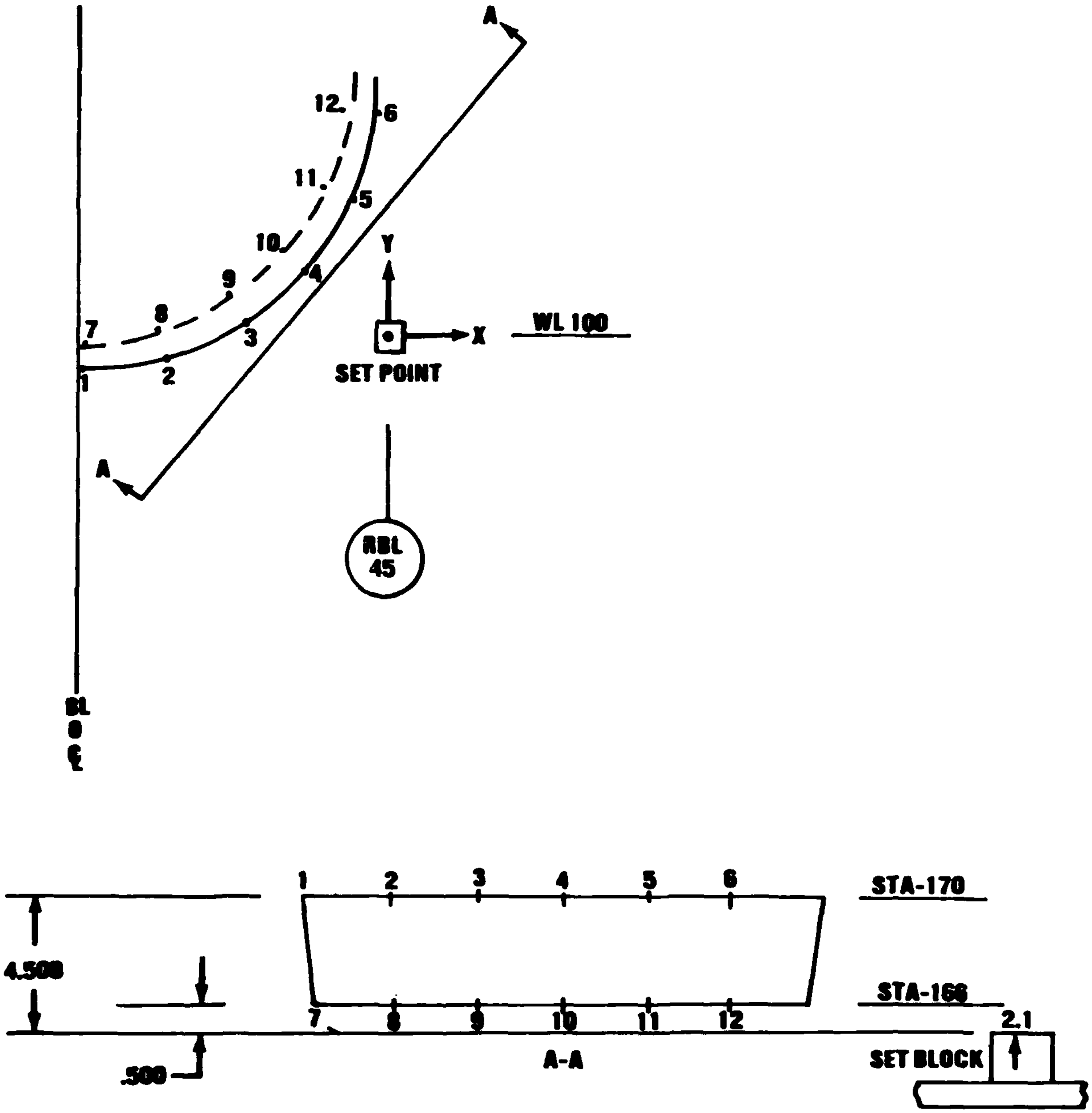
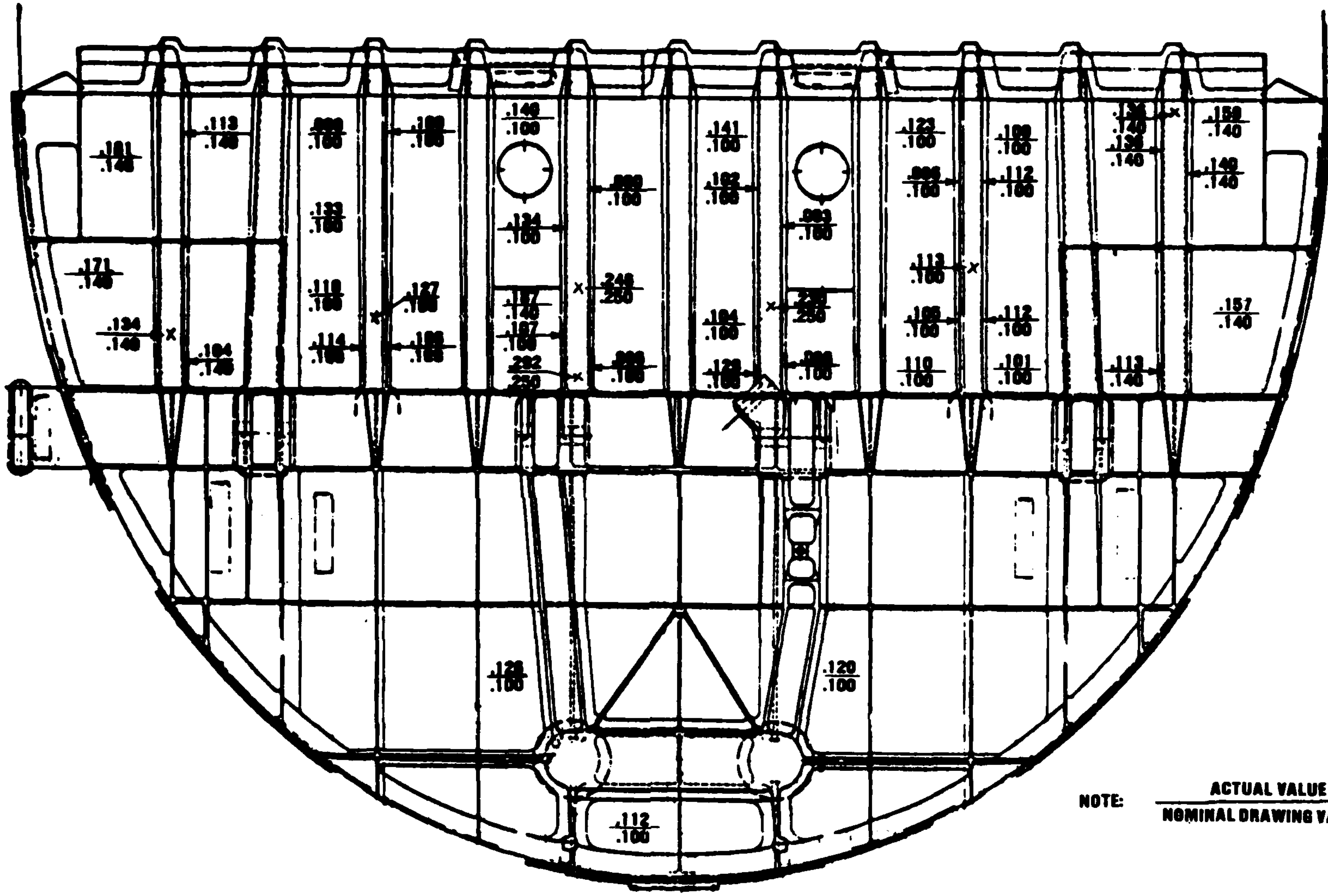


Figure 66 In-process Dimensional Check Point Locations

Table 4. In-Process Check-Point Data for Bulkhead Casting M04

Check Point	x		y		z
	Calculated	Actual	Calculated	Actual	Calculated
(RH) 1	45.0000		-2.8818	-2.8980	4.5000
2	33.6606		-1.3210	-1.3777	4.5000
3	22.4227		3.7245	3.6970	4.5000
4	12.5806	12.5620	12.6566		4.5000
5	5.4493	5.4384	24.5277		4.5000
6	1.1765	1.1757	39.3074		4.5000
7	45.0000		-1.6929	-1.7139	4.5000
8	33.4105		-0.0237	-0.0447	0.5000
9	22.9569		4.9137	4.8785	0.5000
10	14.1226	14.0960	12.2628		0.5000
11	7.3420	7.3229	23.9782		0.5000
12	3.0326	3.0146	38.3428		0.5000
(LH) 1	45.0000		-2.8818	-2.8980	4.5000
2	33.6606		-1.3610	-1.3715	4.5000
3	22.4227		3.7245	3.7086	4.5000
4	12.5806	12.5479	12.6566		4.5000
5	5.4493	5.4266	24.5277		4.5000
6	1.1765	1.1671	39.3974		4.5000
7	45.0000		-1.6929	-1.7134	0.5000
8	33.4105		-0.0237	-0.0386	0.5000
9	22.9569		4.9137	4.8928	0.5000
10	14.1226	14.0844	12.9628		0.5000
11	7.3420	7.3103	23.9782		0.5000
12	3.0326	3.0191	38.3428		0.5000



NOTE: ACTUAL VALUE / NOMINAL DRAWING VALUE

Figure 67 Randc.m Thickness Measurements on Bulkhead Casting M04

Table 5. Mechanical Properties for Bulkhead Castings M04 and M07
(Based on specimens machined from integrally cast coupons)

Serial Number	Date Poured	Bar Size	UTS (psi)	UYS (psi)	Elongation (percent)
M04	3/3/78	0.357 RD	49,000*	42,100	4*
		0.357 RD	52,300	43,300	5
		0.357 RD	51,500	41,900	7
		Requirement:	50,000 min.	40,000 min.	5 min.
		0.48 x 0.150 FLT	48,900	42,700	3
		Requirement:	40,000 min.	30,000 min.	3 min.
M04	4/25/78	0.357 RD	51,700	43,900	5
		0.357 RD	53,100	43,500	8
		0.357 RD	52,600	42,800	9
		Requirement:	50,000 min.	40,000 min.	5 min.
		0.48 x 0.134 FLT	48,900	38,900	4
		0.48 x 0.145 FLT	51,300	42,100	5
		Requirement:	40,000 min.	30,000 min.	3 min.

*Properties deemed acceptable for purposes of this casting.

Therefore, a savings of \$4,354.50 is realized by fabricating the bulkhead by casting methods. The total cost savings percentage is as follows:

$$\Delta \text{ cost} = \frac{12484 - 8129.50}{12484} (100) = 34.9\%$$

SECTION III

PHASE IV, TASK 2—FABRICATION OF DEMONSTRATION COMPONENTS AT HITCHCOCK INDUSTRIES, INC.

A. INTRODUCTION

The second source foundry for the CAST program, Hitchcock Industries, Inc. of Minneapolis, Minnesota also produced 10 bulkhead castings (Fig. 68). This portion of the program was conducted in order to demonstrate that the casting process, as optimized in Phase II, "Manufacturing Methods," was transferable from the Boeing foundry to the Hitchcock foundry and would yield reproducible results.

Hitchcock used all of the tooling furnished by Boeing, including patterns, flasks, chills, and heat-treat fixture, in the production of their castings. The transfer of tooling and technology from Boeing to Hitchcock proceeded very smoothly.

Figure 69 shows an overall view of the area where molding, assembling, melting, and pouring were performed in the Hitchcock foundry. Figure 70 shows the layout of Hitchcock's work area.

B. VARIATIONS IN PROCEDURES

The foundry practices and resulting Manufacturing Plan (Appendix A) established in Phase II were applied by Hitchcock Industries in the production of their 10 bulkhead castings, with only a few variations as will be noted. These variations involved the use of normal Hitchcock foundry procedures.

1. Mold Preparation

In order to aid the running of the thin walls of the casting, the mold segments were vented with 1/8-inch-diameter drilled holes and grooved vertically with a file to a depth of about 1/16 inch. These vent holes and grooves in a corrugated section of the mold are shown in Figure 71.

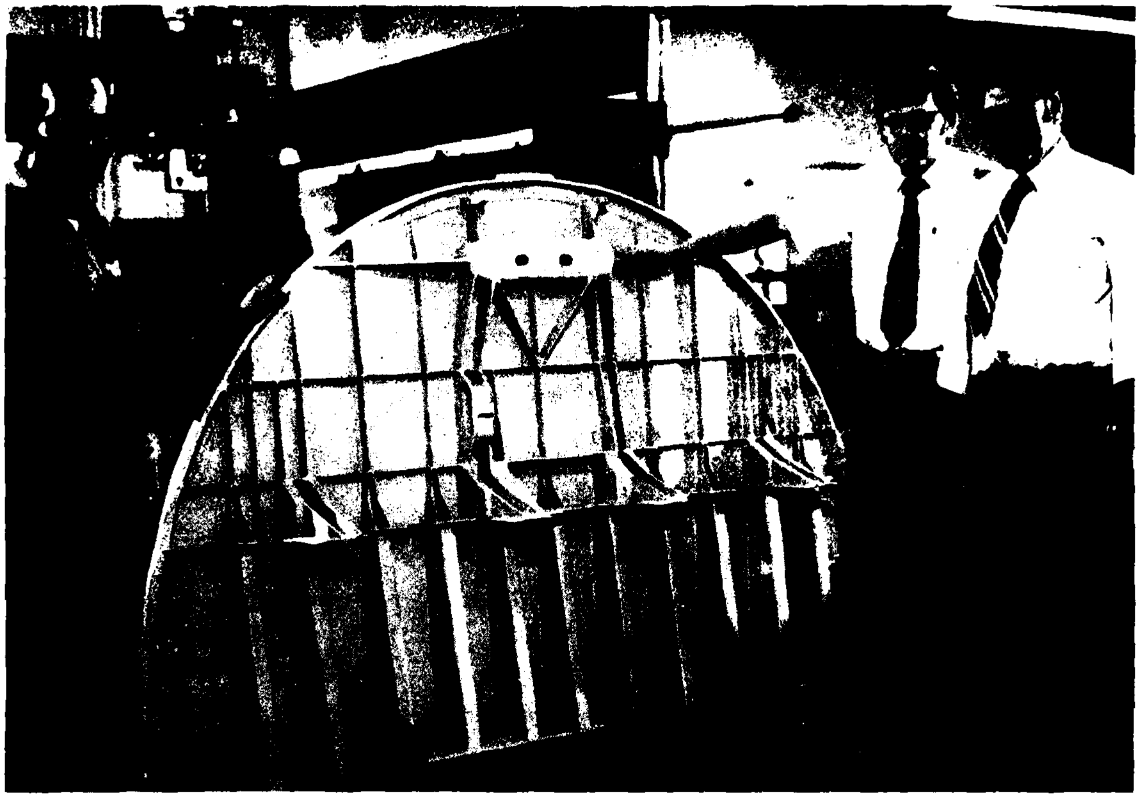


Figure 68 Hitchcock Bulkhead Casting No. 8

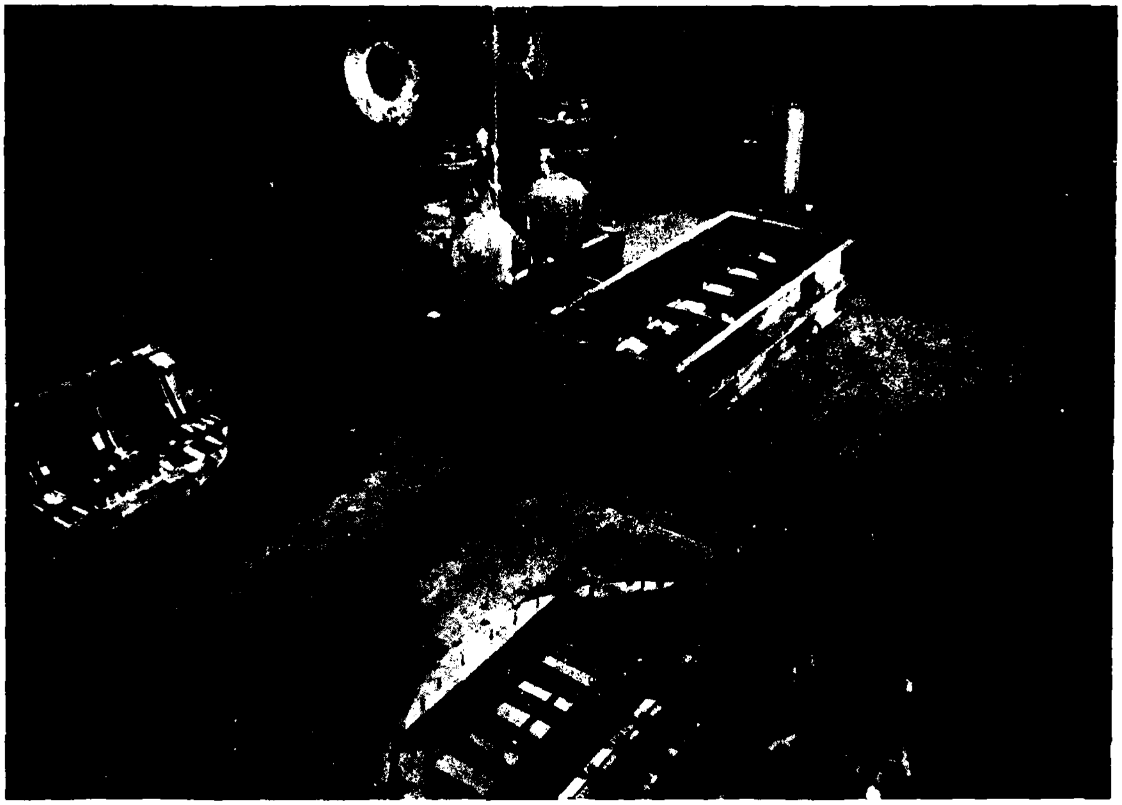


Figure 69 Overall View of Cast Program Foundry Area at Hitchcock Industries, Inc.

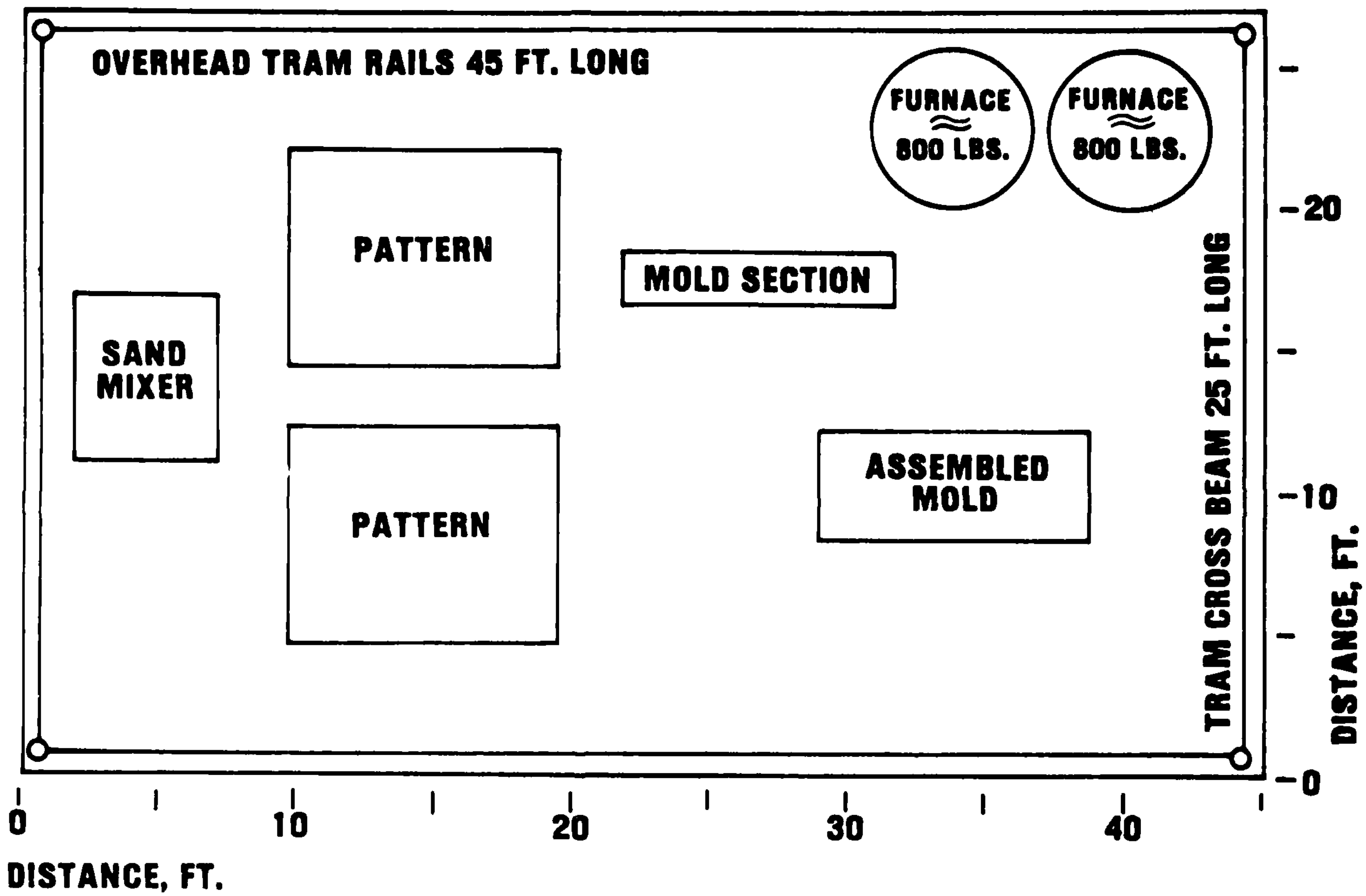


Figure 70 Layout of Foundry Work Area
at Hitchcock Industries, Inc.

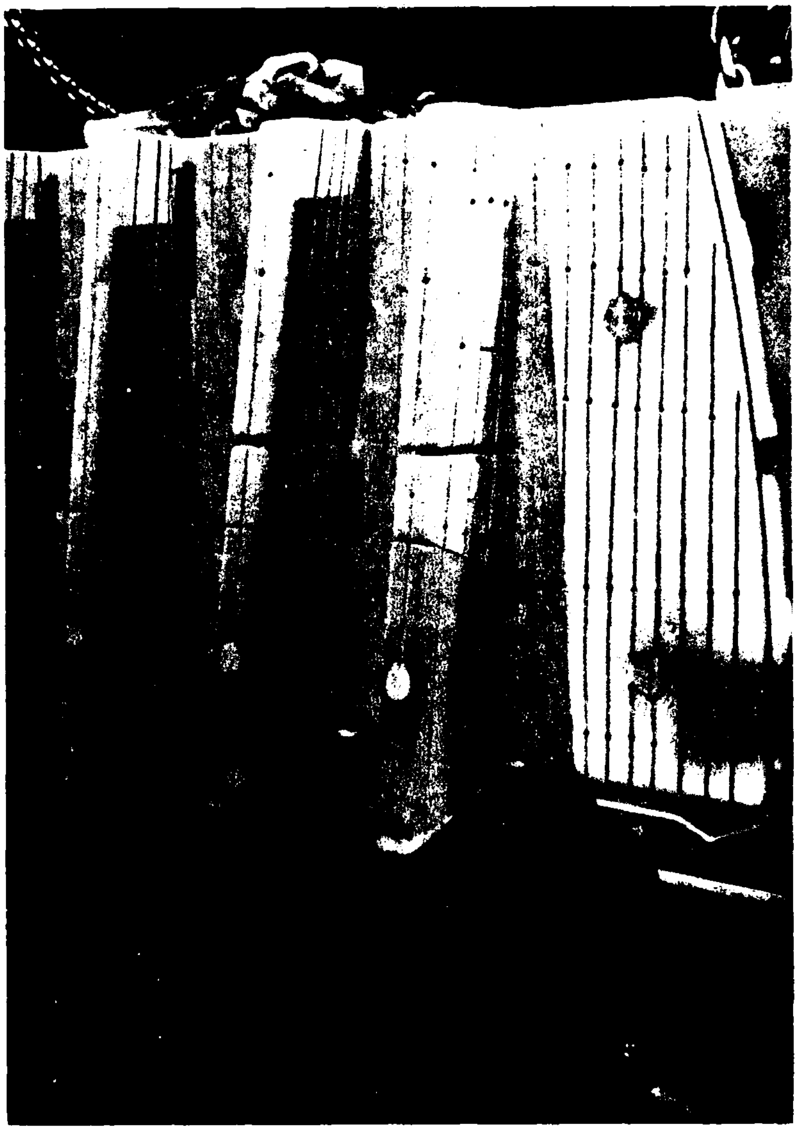


Figure 71 Grooves and Vent Holes in a Corruated Mold Segment

Mold segments were torched to skin dry the mold surface and then were sprayed with an insulating material (mold wash) called Pyroseal. The Pyroseal was burned off by retorching the mold surface. The mold surface then was hand rubbed to remove excess Pyroseal and to smooth the surface. Figure 72 shows the torch drying and Pyroseal spraying operations.

The surfaces of the mold that form the mold/metal interface then were coated with amorphous carbon.

2. Metal Preparation

Melting was accomplished in two furnaces, each containing a removable crucible. Approximately 800 pounds of metal were melted in each furnace.

Degassing of the melt was performed at the pouring temperature of 1450°F, rather than at 1300-1325°F as was done at Boeing. Effectiveness of degassing was determined by allowing the metal sample to solidify in a vacuum freeze chamber at 30 inches of mercury.

3. Pouring

The crucibles (Fig. 73) containing the molten metal were lifted out of the furnaces by cranes and poured directly into the mold, which was only approximately 14 feet away (see Figs. 69 and 70).

4. Mold Shakeout

After the flasks were stripped, the mold was placed in an oven (Fig. 74) and baked at 700°F for 8 hours in order to burn off the binder in the sand. This operation resulted in all the sand falling off the casting (Figs. 75 and 76).

Figure 77 shows the protective skin formed at the casting surface by the Pyroseal mold coating. This skin prevents penetration of the sand by the metal and gives a quite smooth casting surface.

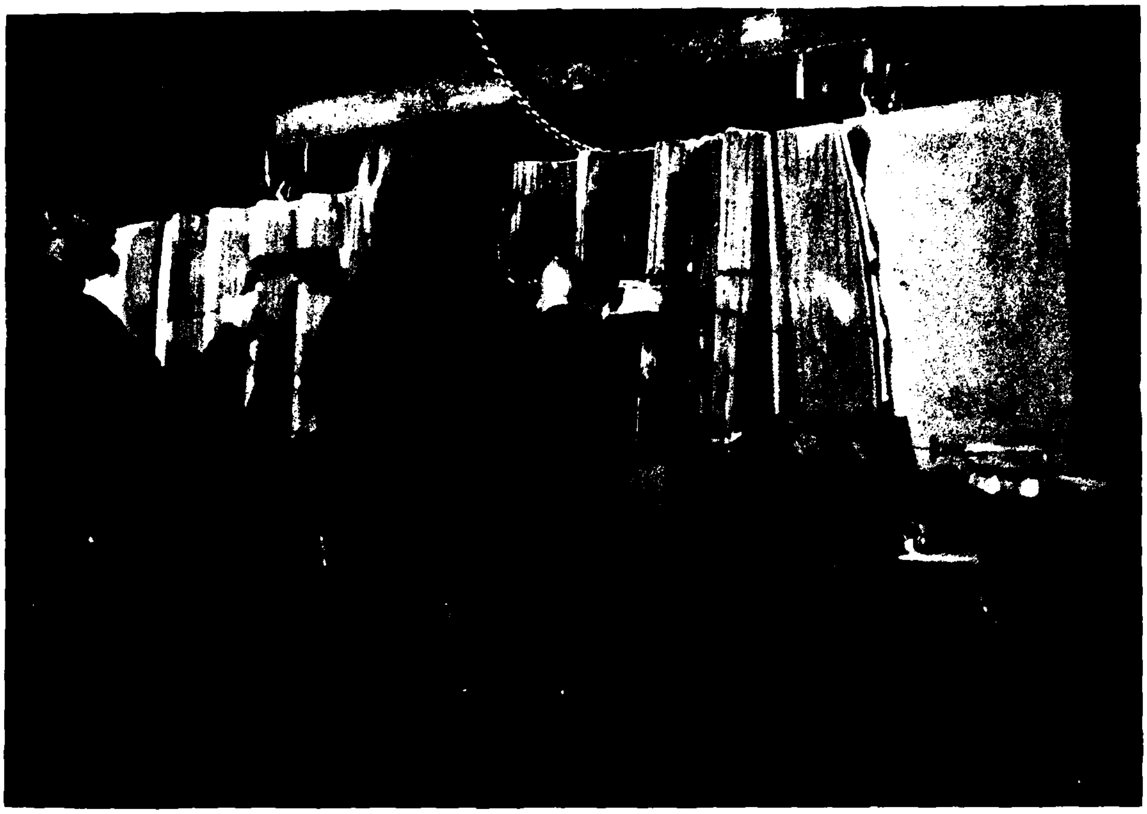


Figure 72 Torch Drying of Mold Surface and Spray Application of Pyroseal Mold Wash

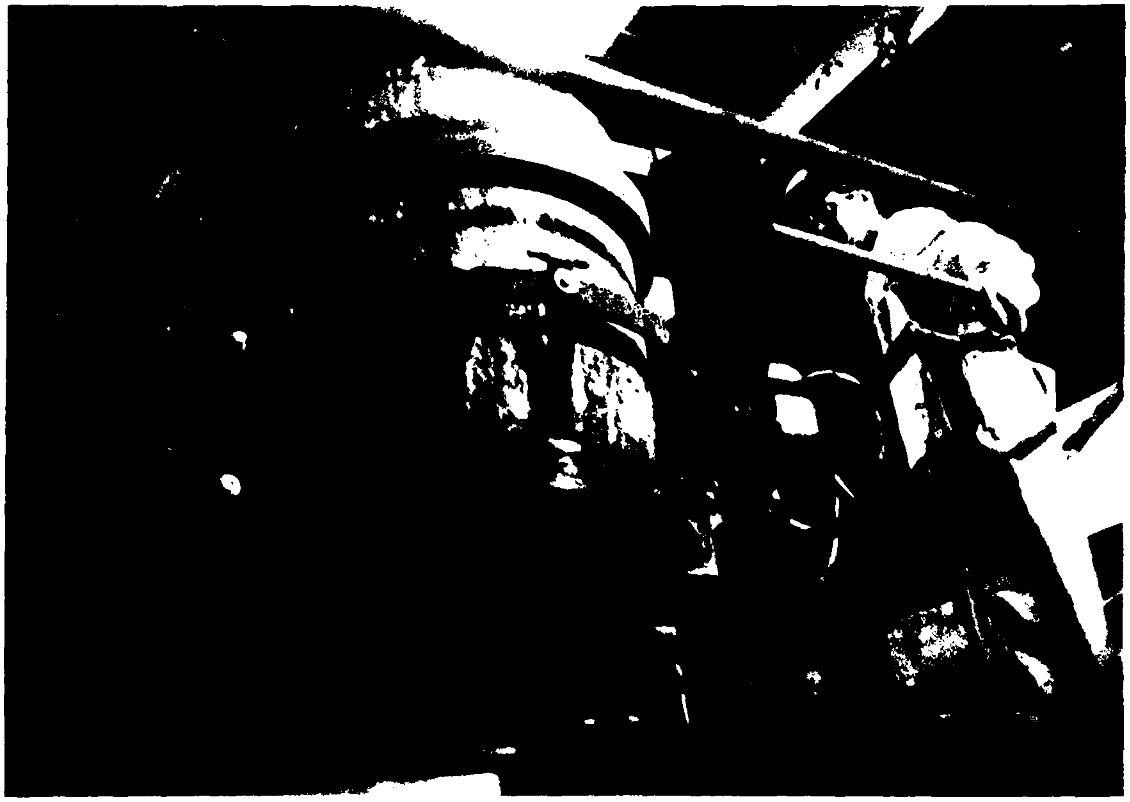


Figure 73 Crucible in Pouring Shank

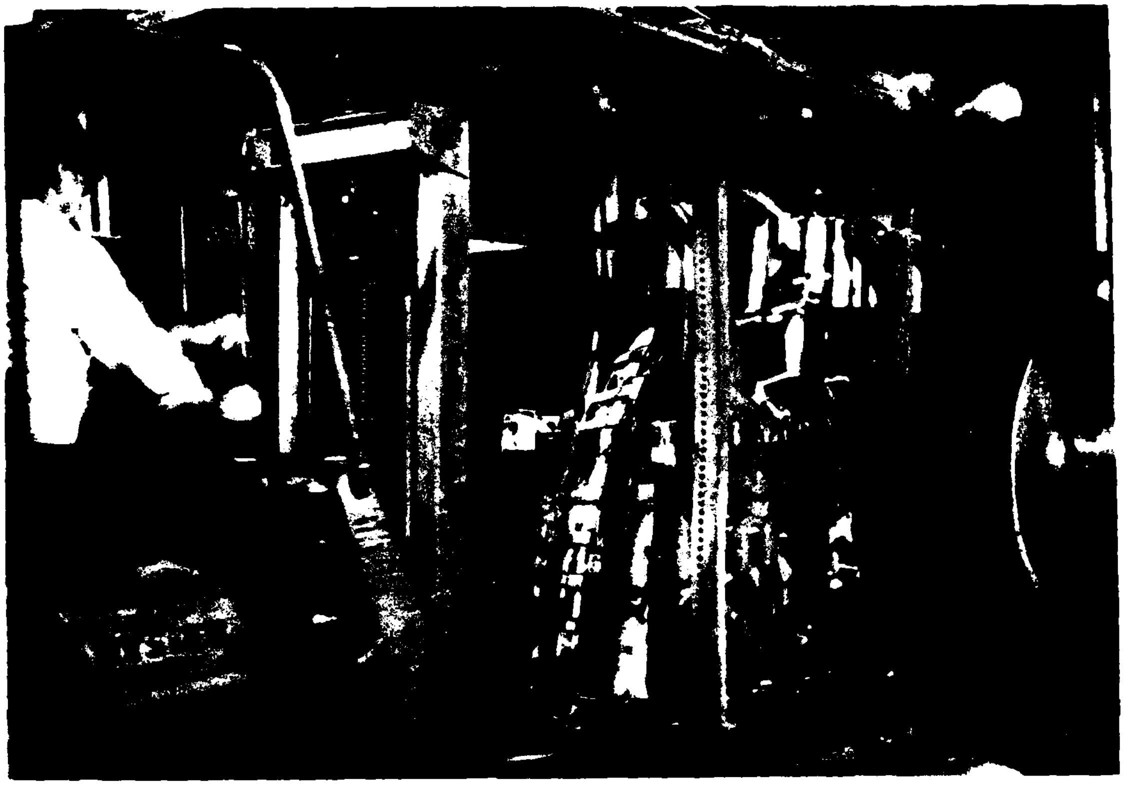


Figure 74 Mold and Casting being Placed in Oven for Burn-off of Sand Binder

Figure 75 Casting After Removal from Bakeout Oven

Figure 76 Bakeout Oven after Casting was Removed,
Showing Sand on Floor

Figure 77 Protective Skin Formed at Casting Surface by Pyroseal Mold Coating

Table 6 presents a summary of foundry data for the 10 Hitchcock castings. Included are the ladle chemistry and the pouring date, temperature, and time for each casting. Results of visual, penetrant, and radiographic inspections and major process differences are summarized also.

C. QUALITY CONTROL

Quality control procedures for the 10 bulkhead castings produced at Hitchcock Industries were similar to those used at Boeing.

1. X-Ray Inspection

Approximately 99% of all radiographs that were taken of the castings showed Grade B or better.

2. Penetrant Inspection

General comments relative to results of penetrant inspection are presented in Table 6, as previously noted.

3. DAS (Dendritic Arm Spacing)

DAS measurements were made on the bulkhead castings at 26 locations as shown in Figure 78, and are presented in Table 7.

4. Ultrasonic Inspection

No ultrasonic inspections for internal defects were performed by Hitchcock Industries. Some ultrasonic inspection for defects will be done by Boeing on the Hitchcock castings.

5. Dimensional Inspection

Random thickness measurements were obtained ultrasonically and are presented in Figures 79 and 80 for Hitchcock castings 2 and 9, respectively.

Table 6. Foundry Data Summary--Hitchcock-Produced Bulkhead Castings

Cast-ing No.	Melt No.	Pot No.	Cu	Si	Fe	Mn	Zn	Mg	Ti	Be	Date	Temp. (°F)	Time (sec.)	Inspection Remarks
			Ladle Chemistry (%)								Pouring			
		Specified:	0.20 max.	6.5-7.5	0.10 max.	0.10 max.	0.10 max.	0.55-0.65	0.10-0.20	0.04-0.07				
1	DA7-100	1	0.01	6.50	0.10	0.01	0.02	0.68*	0.12	0.06	9-18-78	1450	77+	Many misruns in ribs and corrugation side walls. Some shrinkage porosity at rib junctions. Some light shrinkage and sponge porosity in webs outside corrugations. Some dross in two corrugations.
		2	<0.01	6.67	0.12*	0.01	0.02	0.60	0.11	0.05				
		3	0.01	6.70	0.10	0.01	0.02	0.64	0.10	0.06				
2	DA7-102	1	0.01	6.71	0.09	0.01	0.02	0.63	0.15	0.06	9-28-78	1450	77+	Fewer misruns than No. 1. Some light microshrinkage in webs.
		2	0.01	6.70	0.10	0.01	0.02	0.61	0.14	0.07				
		3	0.01	6.70	0.10	0.01	0.02	0.63	0.15	0.07				
3	DA7-105	1	0.01	6.80	0.08	0.01	0.02	0.52*	0.19	0.05	10-6-78	1450	77+	Minor misruns mainly in ribs and corrugation side walls. Some shrinkage mainly at ingates on periphery.
		2	0.01	6.90	0.08	0.01	0.01	0.55	0.19	0.05				
4	DA7-106	1	0.02	6.78	0.09	0.01	0.02	0.61	0.16	0.06	10-17-78	1450	77+	Minor misruns mainly in ribs and corrugation side walls. Some microshrinkage mainly in webs between corrugations. Some shrinkage on periphery.
		2	0.02	6.75	0.08	0.01	0.02	0.63	0.16	0.07				
5	DA7-109	1	0.02	6.51	0.08	0.01	0.02	0.61	0.16	0.07	10-26-78	1450	77+	Minor misruns mainly in ribs and corrugation side walls. Some shrinkage on periphery. Some microshrinkage in webs.
		2	0.02	6.70	0.08	0.01	0.02	0.57	0.16	0.07				
6	DA7-112	1	0.02	6.68	0.08	0.01	0.02	0.59	0.16	0.05	11-3-78	1450+	67+	Sprues 14% larger than for Nos. 1-5. No grooving in wall surfaces; only vent holes. Many misruns mainly in webs and corrugation side walls. Some shrinkage on periphery.
		2	0.02	6.88	0.08	0.01	0.02	0.62	0.16	0.07				
7	DA7-116	1	<0.01	6.50	0.09	<0.01	0.01	0.64	0.16	0.07	11-14-78	1450+	67+	Sprues 14% larger than for Nos. 1-5. Minor misruns mainly in corrugation side walls. One chill dropped at heaviest lug. Some microshrinkage in webs.
		2	<0.01	6.70	0.09	<0.01	0.01	0.59	0.16	0.05				
8	DA7-119	1	<0.01	6.69	0.06	<0.01	<0.01	0.65	0.16	0.07	11-21-78	1450+	67+	Sprues 14% larger than for Nos. 1-5. Minor misruns mainly in ribs and corrugation side walls. Some shrinkage on periphery. Some microshrinkage in webs.
		2	<0.01	6.60	0.06	<0.01	<0.01	0.56	0.16	0.04				
9	DA7-122	1	<0.01	6.50	0.06	<0.01	<0.01	0.64	0.16	0.06	12-1-78	1450+	67+	Sprues 14% larger than for Nos. 1-5. Minor misruns, 4 in ribs and 2 in web. Slightly more metal penetration than normal. Some shrinkage on periphery. Some light microshrinkage in webs.
		2	<0.01	6.60	0.06	<0.01	<0.01	0.59	0.16	0.06				
10	DA7-124	1	0.01	6.60	0.08	0.03	0.02	0.69*	0.14	0.06	12-8-78	1450+	67+	Sprues 14% larger than for Nos. 1-5. Minor misruns, 3 in ribs and 1 in web. Only one small penetrant indication (dirt).
		2	<0.01	6.65	0.08	0.02	0.02	0.68*	0.14	0.05				

*Outside specification limits. Acceptable to Engineering.

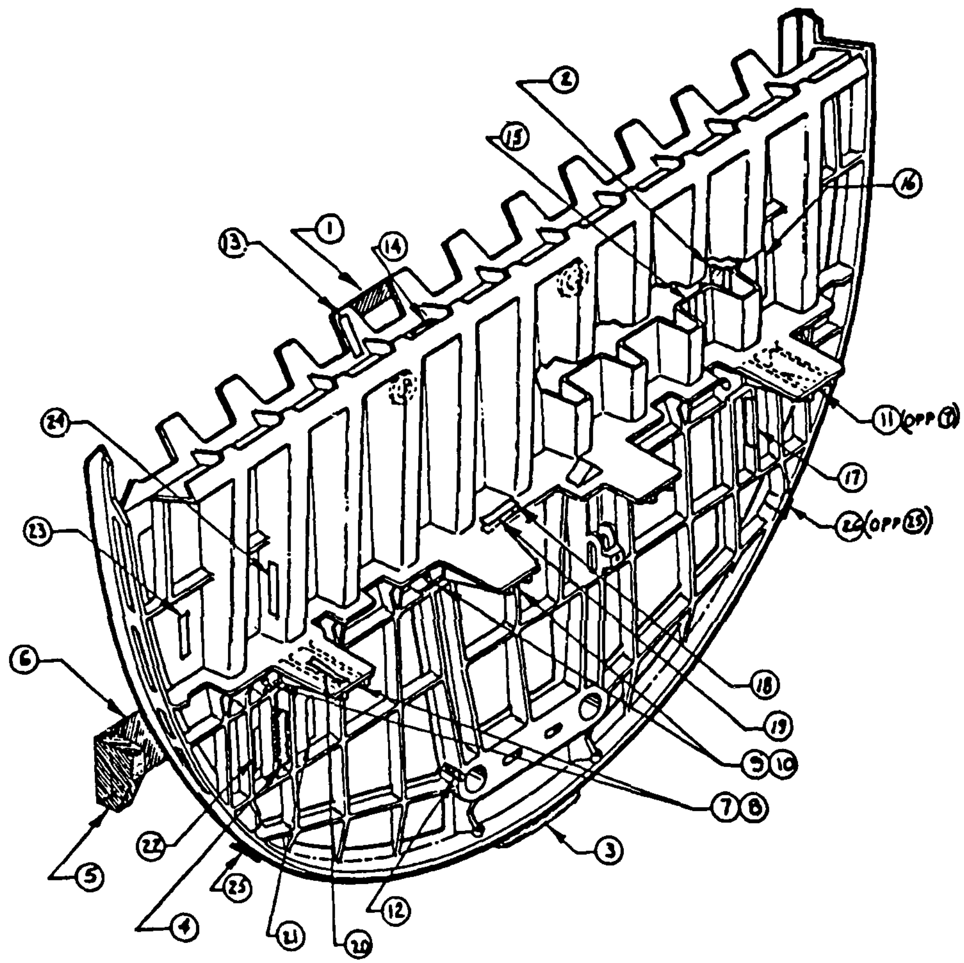


Figure 78 Locations for Measurement of DAS (Dendritic Arm Spacing) on Hitchcock Bulkhead Castings

Table 7. DAS Measurements on Hitchcock Castings Number 2, 7, and 9 1/

Test Location	DAS (0.0001 inch)		
	Casting No. 2	Casting No. 7	Casting No. 9
1	15	2/	17
2	15	13	16
3	17	20	23
4	13	17	15
5	13	16	20
6	14	14	17
7	13	15	16
8	14	14	17
9	14	13	17
10	13	14	13
11	11	13	15
12	11	15	15
13	11	20	27
14	12	15	15
15	12	12	12
16	11	14	11
17	22	21	19
18	16	19	16
19	13	17	15
20	14	21	18
21	14	10	14
22	15	15	14
23	14	15	18
24	14	14	17
25	20	20	19
26	22	19	23

1/ DAS measurements made to date. Additional measurements will be made on other selected castings.

2/ Not available - ear broke off.

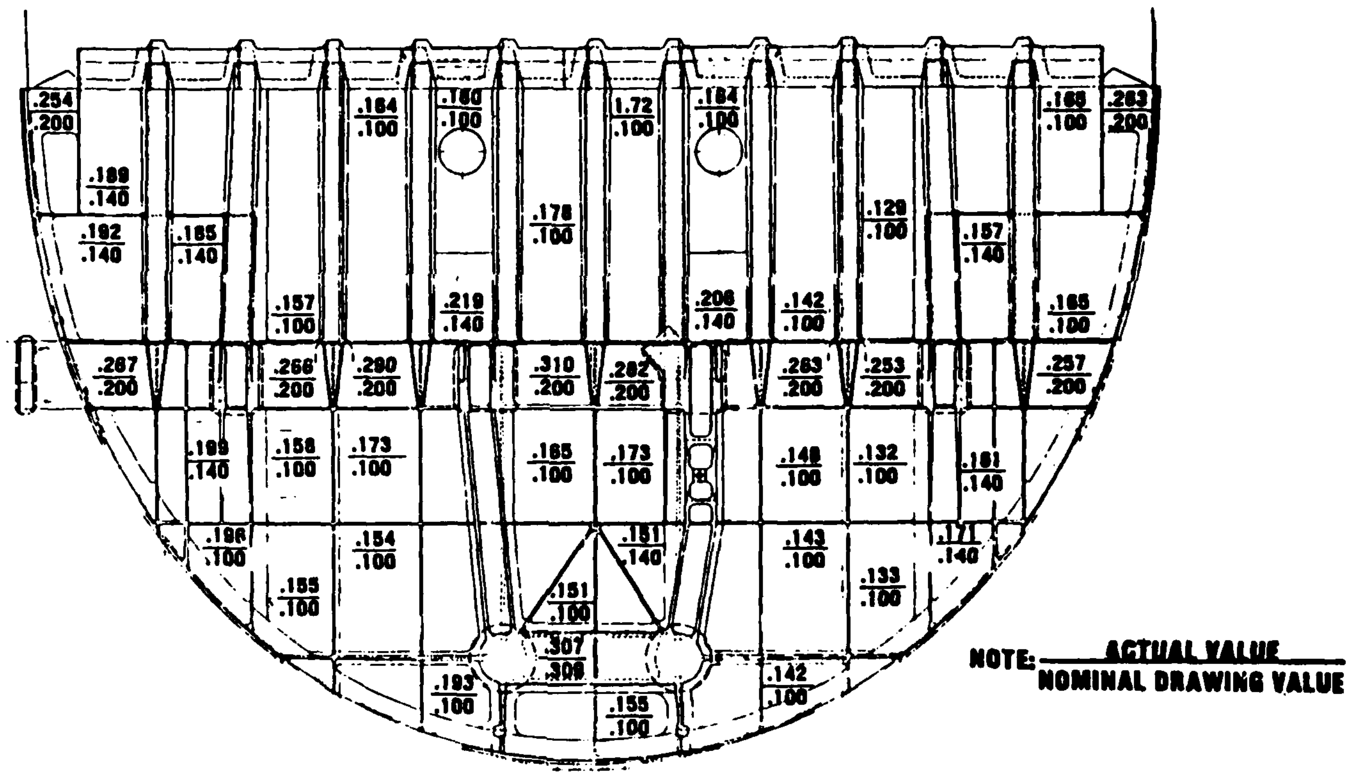


Figure 79 Random Thickness Measurements on Hitchcock Casting No. 2

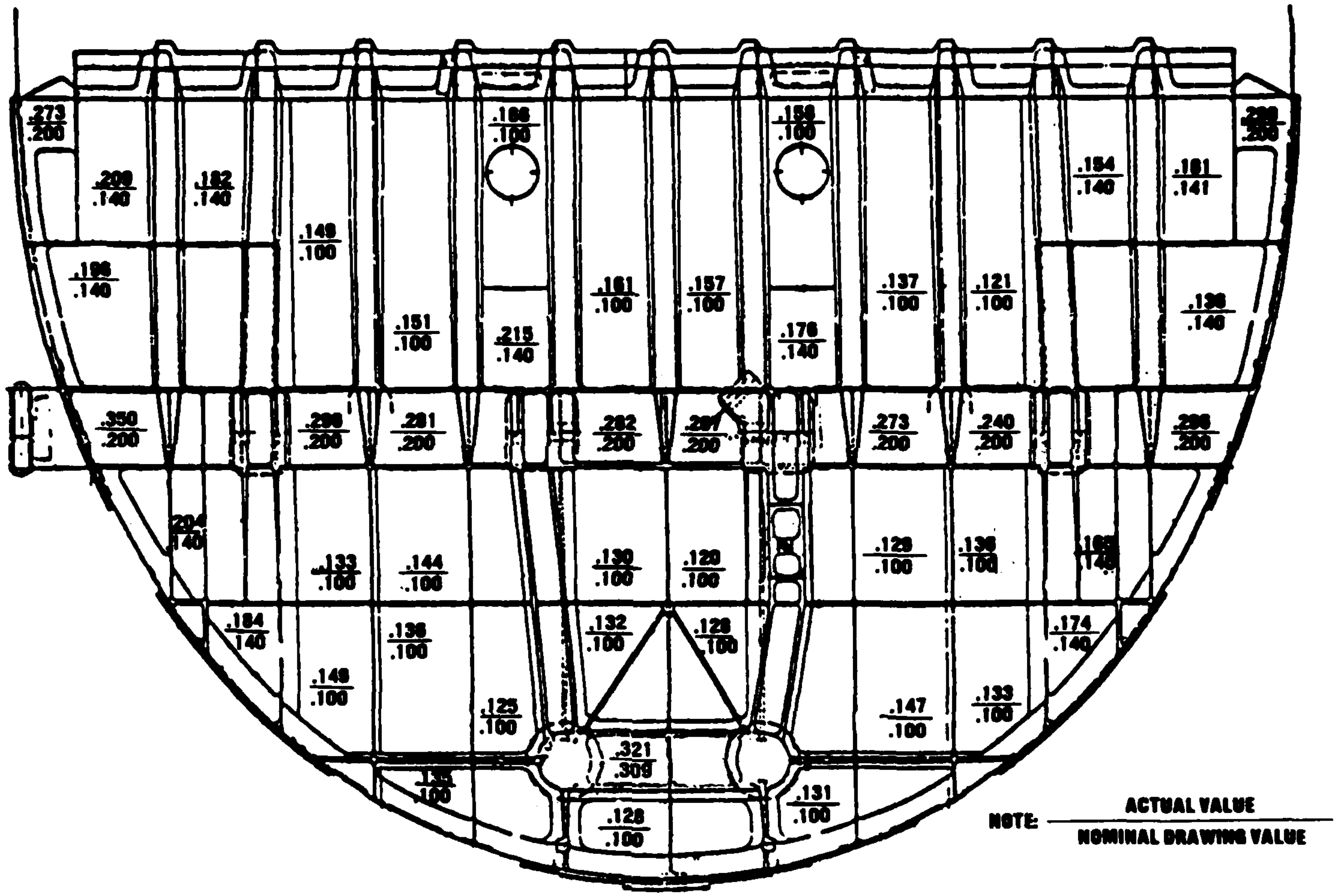


Figure 80 Random Thickness Measurements on Hitchcock Casting No. 9

These castings were in the as-cast, uncleaned condition. The actual values are shown above the nominal drawing thicknesses.

It is noted that the thickness measurements in certain web and channel areas are above the nominal drawing values. The reason for these excessive thickness indications will be investigated in detail in following work in Phase V of the program, where castings will be sectioned for nondestructive inspection cross-check.

D. DISPOSITION OF CASTINGS

Casting numbers 8 and 10 were weld corrected and completely cleaned up for display purposes. These castings were not heat treated. Number 8 was shipped to Boeing for display, and it is planned to ship number 10 to the Air Force for display.

Casting numbers 2 and 9 were heat treated and shipped to Boeing for cut-up for mechanical property test bars and nondestructive inspection cross-check. This work will be accomplished in Phase V, Structural Test and Evaluation, of the program.

Casting numbers 4 and 5 were weld corrected, heat treated, and shipped to Boeing for possible additional material property testing.

The remaining four castings, numbers 1, 3, 6, and 7, were shipped to Boeing in the as-cast and rough-cleaned condition.

SECTION IV
CONCLUSIONS

In general, the results of the Phase IV work show that the casting specifications and fabrication processes developed for manufacture of the cast YC-14 station 170 body/nose landing gear support bulkhead will attain the CAST program goals and objectives.

Based upon the work conducted during Phase IV, the following conclusions are drawn:

1. Dimensional tolerances were consistently maintained from casting to casting. However, some of the dimensions observed did not meet the engineering drawing requirements. In a production situation, these could have been corrected by changing the pattern.
2. Based upon the results from the integral attached coupons, the engineering design requirements for mechanical properties were satisfied.
3. The original cost savings target of 30% was exceeded by the final cost savings estimate of 35% with no weight penalty.
4. The overall reproducibility of the bulkhead casting process from one foundry to another has been well demonstrated, as revealed by a comparison of castings from the two foundries involved in this program. Some slight differences in dimensional control and casting quality exist between the two foundries due to normal variations in detail production techniques, but, all in all, the technology transfer achieved from the process development to actual fabrication of castings in a second production foundry was excellent.
5. Hydrogen contamination of molten aluminum can be reduced using a crucible that is transferred from the furnace and poured directly into the mold. This is opposed to transferring the metal from the furnace to the crucible and then to the mold.
6. Weld correction of castings is needed to reduce the quantity of rejected castings, thereby holding the overall costs to a minimum.
7. Preproduction castings are necessary to establish a detailed manufacturing plan that must be followed throughout the fabrication of all production castings.

REFERENCES

1. Final Report, "Phase III (CAST)—Detail Design," No. AFFDL-TR-78-7, dated January 1978.

APPENDIX A

MANUFACTURING PLAN FOR YC-14 STATION 170 BULKHEAD

DOCUMENT D180-22820-1

D180-22820-1

CAST ALUMINUM STRUCTURES TECHNOLOGY

(CAST)

MANUFACTURING PLAN FOR YC-14 STATION 170 BULKHEAD

-CAST PROGRAM-

July 1978

Submitted to:

United States Air Force
AFSC Aeronautical Systems Division/PPMNA
Wright Patterson AFB, Ohio 45433

Contract F33615-76-C-3111
Project No. 486U

The Boeing Company
Seattle, Washington 98124

MANUFACTURING PLAN FOR YC-14, STATION 170 BULKHEAD

CAST PROGRAM

D180-22820-1

Contract No. F33615-76-C-3111

CDRL Item 15

Prepared By: L. A. Logan Date: 7/13/78

Approved By: R. G. Christner Date: 7/12/78

Approved By: D. D. Goehler Date: 7/18/78

Approved By: D. E. Strand Date: 7/18/78

Contents

Section		Page
1.0	Introduction	1
2.0	Applicable Documents	1
3.0	Process Plan	1
3.1	Material Storage	1
3.2	Sand Preparation	1
3.2.1	Sand/Binder	1
3.2.2	Strip Time	2
3.2.3	Permeability	2
3.3	Mold and Core Making	2
3.3.1	Pattern Equipment	2
3.3.2	Parting Agent	2
3.3.3	Core Making	4
3.3.4	Mold Making	7
3.3.4.1	Base Plate	7
3.3.4.2	Base Flask	7
3.3.4.3	Molding Flasks	10

Section		Page
3.3.4.3.1	Molding Flasks A1 and B1	10
3.3.4.3.2	Molding Flasks A2 and B2	16
3.3.4.3.3	Molding Flasks A3 and B3	18
3.3.4.4	Filling of Molding Flasks	20
3.3.5	Flask Stripping and Rotation	29
3.3.6	Core Setting	32
3.3.6.1	Base Flask	32
3.3.6.2	Flask A1	32
3.3.6.3	Flask B1	32
3.3.6.4	Flask A2	34
3.3.6.5	Flask B2	34
3.3.6.6	Flask A3	34
3.3.6.7	Flask B3	34
3.3.7	Mold Assembly	37
3.4	Mold Preparation for Pouring	39
3.5	Metal Preparation	39
3.5.1	Material Storage	39

Section		Page

Section		Page
3.5.2	Metal Melting	41
3.5.2.1	Furnace Charging	41
3.5.2.2	Holding Temperature	41
3.5.2.3	Degassing	41
3.5.2.4	Gas Check	41
3.5.2.5	Chemical Analysis	43
3.5.2.6	Metal Heat Up	43
3.6	Ladle Fill	44
3.6.1	Ladle Preheat	44
3.6.2	Ladle Filling	44
3.6.3	Pouring Temperature Check	45
3.7	Pouring	45
3.8	Mold Shakeout	45
3.9	Casting Cleanup	46
3.10	Inspection	46
3.10.1	Visual	46

Section		Page

Section		Page
3.10.2	DAS Measurement	46
3.10.3	X-ray	46
3.10.3.1	Radiographic Procedures	47
3.10.3.2	Required Inspections	47
3.10.3.3	Acceptance Criteria	47
3.10.3.4	Records	47
3.10.4	Penetrant Inspection	47
3.10.4.1	Etch	47
3.10.4.2	Penetrant Inspection Materials	47
3.10.4.3	Required Inspections - Per MIL-I-6866, "Inspection, Penetrant, Method of "	48
3.10.4.4	Acceptance Criteria	48
3.10.4.5	Records	48
3.11	Weld Correction	48
3.12	Weld Correction of Imperfections; Procedures for A357 Aluminum Sand Castings	48
3.12.1	Application Note	49
3.12.2	Typical Casting Imperfections	49

Section		Page
3.12.2.1	Surface Imperfections	49
3.12.2.2	Internal Imperfections	50
3.12.2.3	Misruns	50
3.12.2.4	Cracks	50
3.12.3	Preweld Preparation	51
3.12.3.1	Equipment	51
3.12.3.2	Cutters	51
3.12.3.3	Groove Preparation	51
3.12.4	Preweld Cleaning	52
3.12.5	Welding Considerations	54
3.12.5.1	Welding Process Selection	54
3.12.5.2	Welding Equipment	55
3.12.5.3	Preheating	55
3.12.5.4	Shielding Gases	56
3.12.5.5	Tungsten Electrodes	56
3.12.5.6	Filler Material	57
3.12.5.7	Edge Wetting and Laps	57
3.12.5.8	Interpass Cleaning	58

Section		Page
3.12.5.9	Tailouts	58
3.12.6	Weld Bead Reinforcement Removal	59
3.12.6.1	Weld Bead Shaving	59
3.12.6.2	Bead Shaving Equipment	59
3.12.6.3	Bead Shaving Techniques	59
3.12.7	Weld Correction Procedures	60
3.12.7.1	Weld Correction of Surface Imperfections	60
3.12.7.2	Weld Correction of Internal Imperfections	60
3.12.7.3	Weld Correction of Misruns	62
3.12.7.4	Weld Correcticn of Cracks	63
3.13	Heat Treatment/Straightening	64
3.13.1	Solution Heat Treatment	64
3.13.2	Straightening and Natural Age	65
3.13.3	Artificial Age	65
3.13.4	Inspection of Heat Treated Casting	65
3.14	Mechanical Property Testing	65
3.15	Machine Casting	65

Section		Page
3.16	Inspection	65
3.16.1	Dimensional	65
3.16.2	Penetrant	65

ILLUSTRATIONS

Figure No.		Page
1	Lining 1/2-in. Thick Ceramic Foam Insulation on Outside of -47 Down Sprues	6
2	Core Lifting Hooks	6
3	Lining 3/4-in. Thick Ceramic Foam Insulation on Both Runners of -10 Base Frame	8
4	Steel Screen Locations of YC-14 Station 170 Body Bulkhead Casting, Base Flask	9
5	Chill Locations - Aft Side, YC-14 Station 170 Body Bulkhead Casting	11
6	Chill Locations - Fwd Side, YC-14 Station 170 Body Bulkhead Casting	12
7	Step Gate Locations - Aft Side, YC-14 Station 170 Body Bulkhead Casting	13
8	Step Gate Locations - Fwd Side, YC-14 Station 170 Body Bulkhead Casting	14
9	Attachment of Pads at Corrugated Section	15
10	No Gap Should Be Present Between the Flask Machined Pads and the Pattern Steel Plate	15
11	Clamping a Backing Board to Flask B3	17
12	Locations of Ingate Attachment for A2 Flask Backing Board (Only Two Shown)	17
13	No Gap Should Be Present Between Machined Pads of Any Two Flasks	19

Figure No.		Page
14	Approximate Gagger Locations - Aft Side, YC-14 Station 170 Body Bulkhead Casting	21
15	Approximate Gagger Locations - Fwd Side, YC-14 Station 170 Body Bulkhead Casting	22
16	Placement of Fiberglass Screening Material and Thermogard Insulating Riser Sleeves	23
17	Electrical Wire Locations - Aft Side, YC-14 Station 170 Body Bulkhead Casting	25
18	Installation of Electrical Wires in Thermogard Sleeve	26
19	Placement of Fiberglass Screens Normal to Vertical Risers	26
20	Placement of Slab Cores Over Secondary Runner	27
21	Sand Cavity for Easing Mold Shakeout	27
22	Locations of Mold Shakeout Cavities	28
23	Attachment of Spreader Bar, Crane, and Steel Triangles for Flask Stripping	28
24	Stripping Flask With Four Hydraulic Jacks (Two on Each Side)	30
25	Rotation of Molding Flask	31
26	Core Locations - Fwd Side, YC-14 Station 170 Body Bulkhead Casting	33

Figure No.		Page
27	Core Locations - Aft Side, YC-14 Station 170 Body Bulkhead Casting	35
28	Step Gate Locations of Shelves at WL 130	36
29	Attachment of Guiding Bar to B1 Flask	38
30	Checking Proper Alignment of E, F, and G Cores	38
31	Light Indicator Electrical Wires Hook-up	40
32	Vacuum Freeze Chamber for Gas Check	42
33	Typical Groove Configuration for Weld Correction	53

TABLES

No.		Page
1	Pattern Equipment - Tool Identification Numbers and Names	3
2	Cores to Be Made for YC-14 Station 170 Body Bulkhead Casting	5

1.0 INTRODUCTION

The purpose of this document is to provide the necessary information to fabricate the YC-14 Station 170 Body Bulkhead as an aluminum sand casting. This plan outlines in detail all the operations necessary to produce this part in accordance with drawings 162-00017 and 162-00018.

2.0 APPLICABLE DOCUMENTS

The following documents form part of this plan:

M-XXXX-Aluminum Alloy A357 Castings, Primary Aircraft Structure

W-XXXX-Welding, Fusion, Correction of Primary Structural A357 Aluminum Alloy Castings, process for

D-XXXX-Dendrite Arm Spacing, Aluminum Alloy A357 Castings, Process for Determination

3.0 PROCESS PLAN

3.1 Material Storage

- o All materials should be protectively covered with polyethylene tarp to prevent contamination.

3.2 Sand Preparation

3.2.1 Sand/binder

- o Use AFS 53 & 70 washed and dried silica sand. Maintain sand mixing temperature at 85 $\pm$ 10^{o}F
- o Use a three-part air set binder system consisting of Ashland Linocure AW, BW-3, and C, except as noted.
- o Use a continuous mixer with a minimum capacity of 100 lbs. per minute of mixed sand.
- o Calibrate the mixer to 1.1% binder mixture. Note: Calibrate mixer after every 10 hours of use.

- o Introduce sand and three-part binder system into the continuous mixer and run until a complete mix is obtained.

3.2.2 Strip Time

- o Strip time for cores should be set for 12-15 minutes and 30-45 minutes for molding flasks. Strip time for molds and cores shall not exceed 72 hours.

3.2.3 Permeability

- o Spot check permeability a minimum of five areas on the mold sections and two areas on all cores with a permeability meter. (Optional).
- o Maintain a minimum permeability reading of 100.

3.3 Mold and Core Making

3.3.1 Pattern Equipment

- o A list of the tooling required is given in Table I.

3.3.2 Parting Agent

- o Spray all pattern and core box surfaces with Ashland EP-50 aluminum base parting agent or equivalent. Let dry for 15 minutes and wipe off excess. Recoat surfaces as required.

Table 1

PATTERN EQUIPMENT - TOOL IDENTIFICATION NUMBERS AND NAMES

TOOL IDENTIFICATION NO.	TOOL NAME	TOOL IDENTIFICATION NO.	TOOL NAME
EPATR672043-1	aft side pattern	EPATR672043-25	periphery core box (H)
-2	forward side pattern	-26	periphery core box (J)
-3	molding flask A1	-27	periphery core box (K)
-4	molding flask A2	-28	periphery core box (L)
-5	molding flask A3	-29	periphery core box (M)
-6	molding flask B1	-30	periphery core box (N)
-7	molding flask B2	-31	torque box core box (O-1)
-8	molding flask B3	-32	torque box core box (O-2)
-9	base flask	-33, -34	torque box core box (P)
-10	base frame w/main runners	-35, -36	torque box core box (Q)
-11	spreader bar	-37, -38	corrugated core box (R)
-12	spreader bar	-39, -40	corrugated core box (S)
-13	runner for A2 flask (B-1)	-41, -42	corrugated core box (T)
-14	runner for B2 flask (B-2)	-43, -44	corrugated core box (U)
-15, -16	base core box (A)	-45, -46	corrugated core box (V)
-17, -18	base core box (B)	-47	sprue core box for A1 and B1
-19, -50	base core box (C)	-48	sprue core box for A3 and B3
-20, -20	base core box (D)	-49	basin plug core box
-22	periphery core box (E)	-51	sprue core box for A2 and B2
-23	periphery core box (F)	-52	pouring basin core box
-24	periphery core box (G)		

3.3.3 Core Making

- o Make the quantity of cores indicated in Table II with AFS53 silica sand mixed with Linocure binder. As noted, cores 0-1 and 0-2 must be made with sodium silicate - CO_2 binder.
- o Place two 3/4" dia. X1" copper chills (No. 33) on each end of 0-1 and 0-2 cores.
- o Place one No. 41 copper chill each on marked location in core boxes E&G.
- o Place two No. 42 copper chills on marked locations in core box F.
- o Place two 1/4" x 1" x 4-1/2" and three 1/4" x 1" x 2" copper chills on marked locations on core box Q.
- o Place a hook on each of the four basin plug cores (-49). These hooks, which must be placed 90^{o} to any plug wall, will be used to remove plugs from basin during pouring.
- o In fabrication of the -47 spure core, line the outside surface of the down sprue with 1/2" thick ceramic insulation (see Figure 1).

  Note: Insulation material should be a refractory ceramic such as silica or alumina. It must be dry and contain no chemically combined water. Under no circumstances should plaster be used.
- o In the -51 sprue cores, line the outside of the double sprues which feed the secondary runners with 1/4" thick ceramic insulation. Line the outside of the sprues with insulation 12" long and the inside 6" long. No insulation is needed on the single down sprue which feeds the primary runner system.
- o Mold lifting hooks into spure cores -47, -48, and -51 to facilitate core stripping. These hooks should be reinforced so they will not pull out during stripping (see Figure 2).
- o Cure all cores at room temperature for a minimum of 1 day and a maximum of 30 days before use. All cores not used

Table 2

CORES TO BE MADE FOR YC-14 STATION 170 BODY BULKHEAD CASTING

CORE NAME	QUANTITY	CORE NAME	QUANTITY
base core (A)	1	torque box core (O-2) [2] [3]	1
base core (B)	2	torque box core (P)	1
base core (C)	1	torque box core (Q) [2]	1
base core (D)	1	corrugated core (R)	2
periphery core (E) [2]	1	corrugated core (S)	2
periphery core (F) [2]	1	corrugated core (T)	5
periphery core (G) [2]	1	corrugated core (U)	1
periphery core (H)	1	corrugated core (V)	1
periphery core (J)	1	sprue core (-47) [1]	2
periphery core (K)	1	sprue core (-48) [1]	2
periphery core (L)	1	basin plugs (-49)	4
periphery core (M)	1	sprue core (-51) [1]	2
periphery core (N)	1	pour basin (-52)	2
torque box core (O-1) [2] [3]			

[1] Do not patch the sprue cores in the area of the down sprues. Remake cores if there is any damage to the sand in these areas.

[2] Incorporate copper chills as outlined in core box.

[3] Make from #1 fine sand w/sodium silicate/CO_2 binder.

FIGURE 1 LINING 1/2 INCH THICK CERAMIC FOAM INSULATION ON OUTSIDE OF -47 DOWN SPRUES

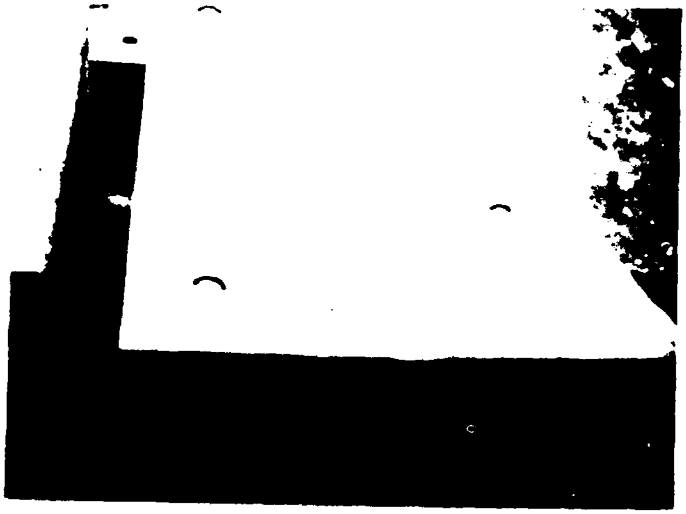


FIGURE 2 CORE LIFTING HOOKS

6

within 30 days should be discarded and remade.

- o After making the cores, protectively cover with clear plastic and store in a dry place.

3.3.4 Mold Making

3.3.4.1 Base Plate

- o Level base plate to within .008 inch.

3.3.4.2 Base Flask

- o Line both runners of base frame (-10) with 3/4" thick ceramic foam insulation (see Figure 3).
- o Assemble base flask (-9) to base frame (-10) in an inverted position and level to within .008 inch.
- o Clamp base flask to base frame to prevent movement of base frame.
- o Place a tin plated steel screen with .075" dia. holes, 50% open area, at locations 1 in both pouring wells. (See Figure 4).
- o Place a tin plated steel screen with .050" dia. holes, 50% open area, at locations 2 in both pouring wells. (See Figure 4).
- o Place 3/8" ID washers and 5/16"-18 wing nuts on core studs (optional).
- o Fill base flask with AFS 70 silica sand mixed with binder. Strike surface off and when sand has cured, remove the sand to .005 inch below the surface of the base flask frame.
- o Let sand cure and strip base flask from base frame after minimum time specified in section 3.2.2.
- o Roll over the base flask and place it on base plate.
- o Clean base flask.
- o Set cores as described in Section 3.3.6.
- o Apply an amorphous carbon coating (approximately .001 inch thick) to base core and mold surfaces. Be sure to apply coating to rib cavities.

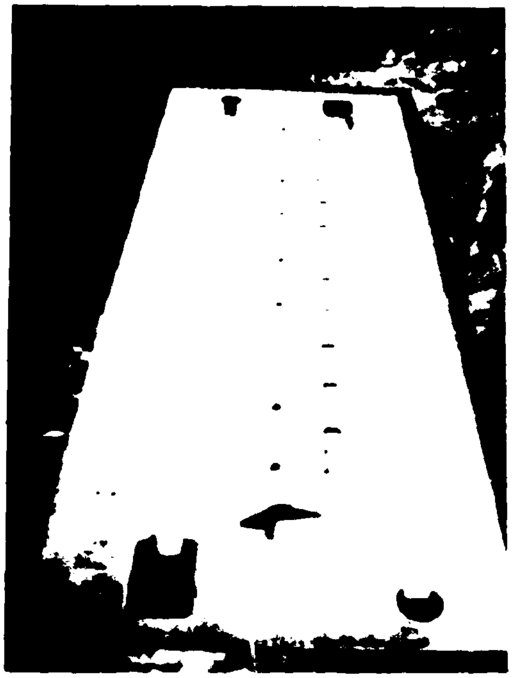


FIGURE 3 LINING 3/4 INCH THICK CERAMIC FOAM INSULATION ON BOTH RUNNERS OF -10 BASE FRAME

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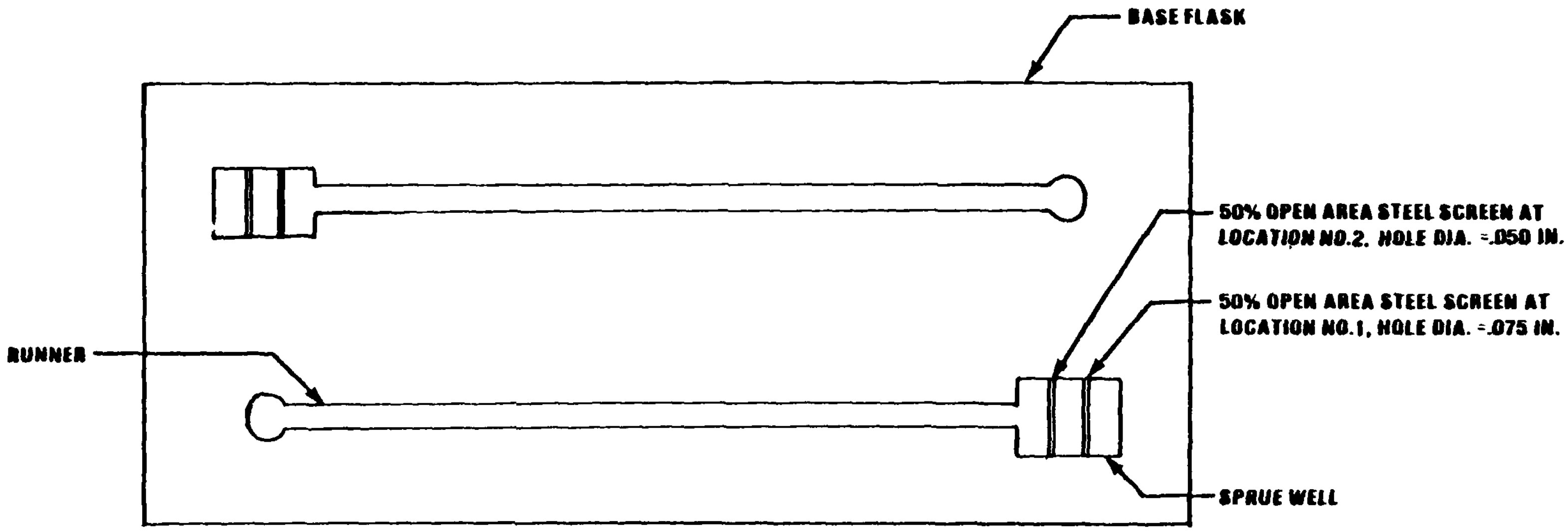


FIGURE 4 STEEL SCREEN LOCATIONS OF YC-14 STATION 170 BODY BULKHEAD CASTING, BASE FLASK

o Place steel wool in each pouring well at the base of the sprue.

3.3.4.3 Molding Flasks

o Level molding surface of aft side pattern (-1) and forward side pattern (-2) to within .005 $^{+.003}_{-.005}$ inch.

o Spray aft and forward patterns with parting agent specified in section 3.3.2.

3.3.4.3.1 Molding Flasks A1 and B1

o Set in place, as shown in Figures 5,6,7 and 8 all chills and step gates contained in molding flasks A1 and B1. They should be 39 step gates in A1 and 46 step gates in B1.

o Pin the 1/8" thick pads on the sides of each corrugated section, Figure 9.

Note: Be sure to remove the pins while filling the flask with sand. The weight of the sand will hold the pads in place.

o Place 3/8" ID washers and 5/16" - 18 wing nuts on core bolt studs. (B1 side only).

o Coat backing boards for A1 and B1 flasks with parting agent specified in Section 3.3.2. Recoat as often as required.

o Position backing boards for A1 and B1 flasks. Pin and clamp the backing boards to patterns.

Caution: Make sure the edge of the backing board is in line with the rib on which the flask is parted. If the board is not properly aligned, shim as necessary. This is extremely important on Flask B1 because this flask is parted on the B datum plane.

o Fill with AFS 70 silica sand as described in Section 3.3.4.4.

o Set sprue cores (-47) in place on both the forward and aft side patterns.

o Set flasks A1 (-3) and B1 (-6) on aft and forward patterns, respectively.

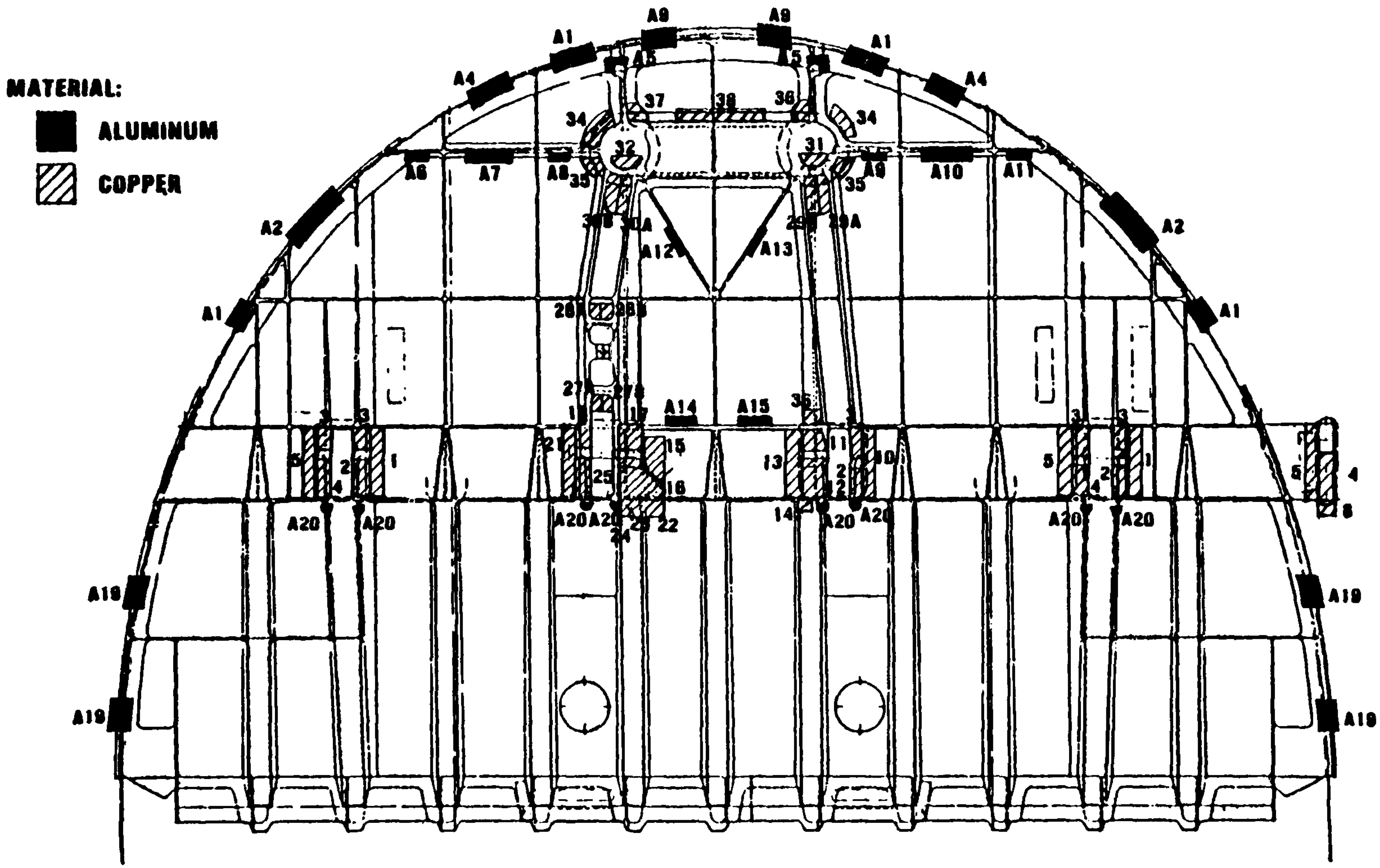


FIGURE 5 CHILL LOCATIONS-AFT SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

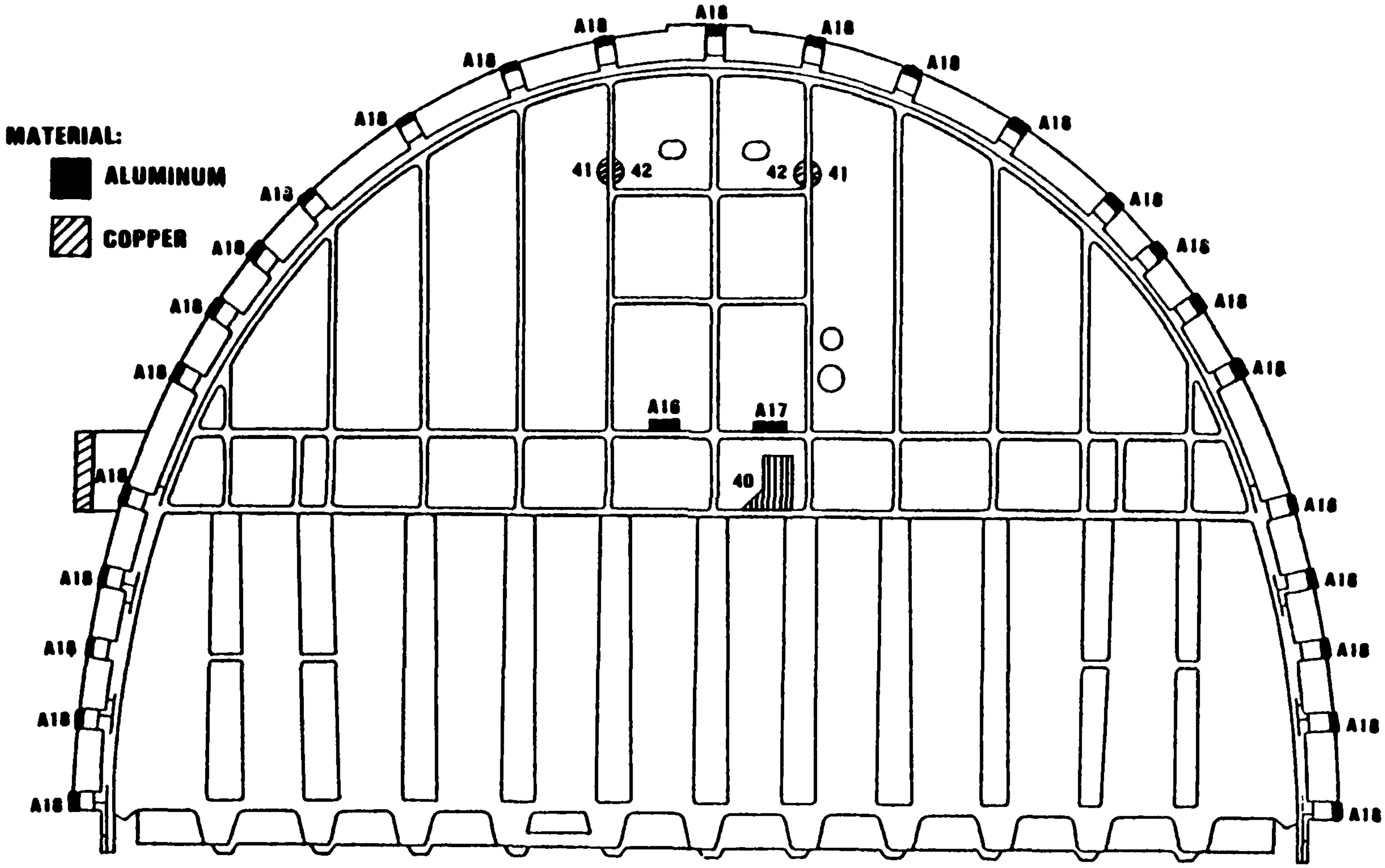


FIGURE 6 CHILL LOCATIONS-FWD SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

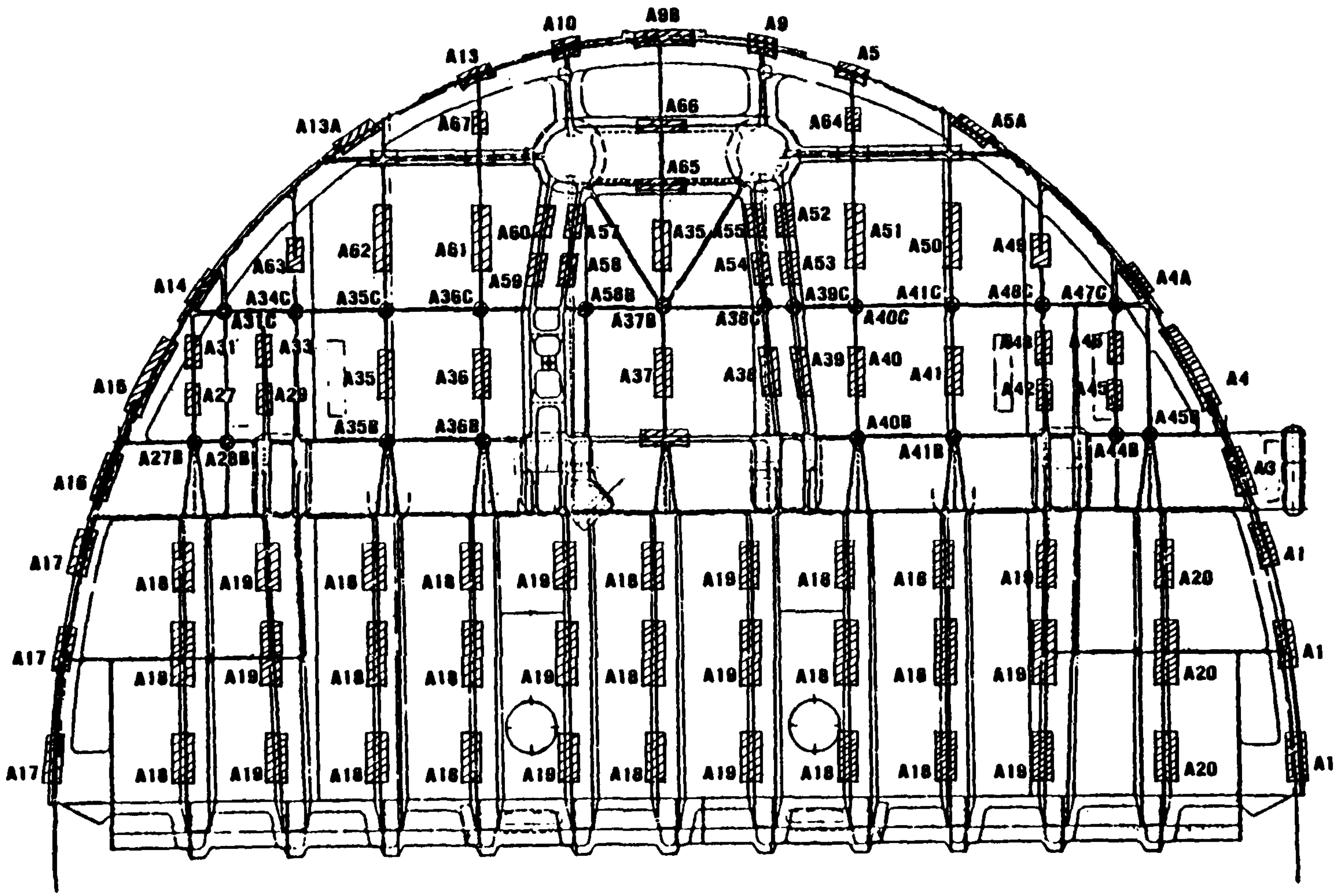


FIGURE 7 STEP GATE LOCATIONS-AFT SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

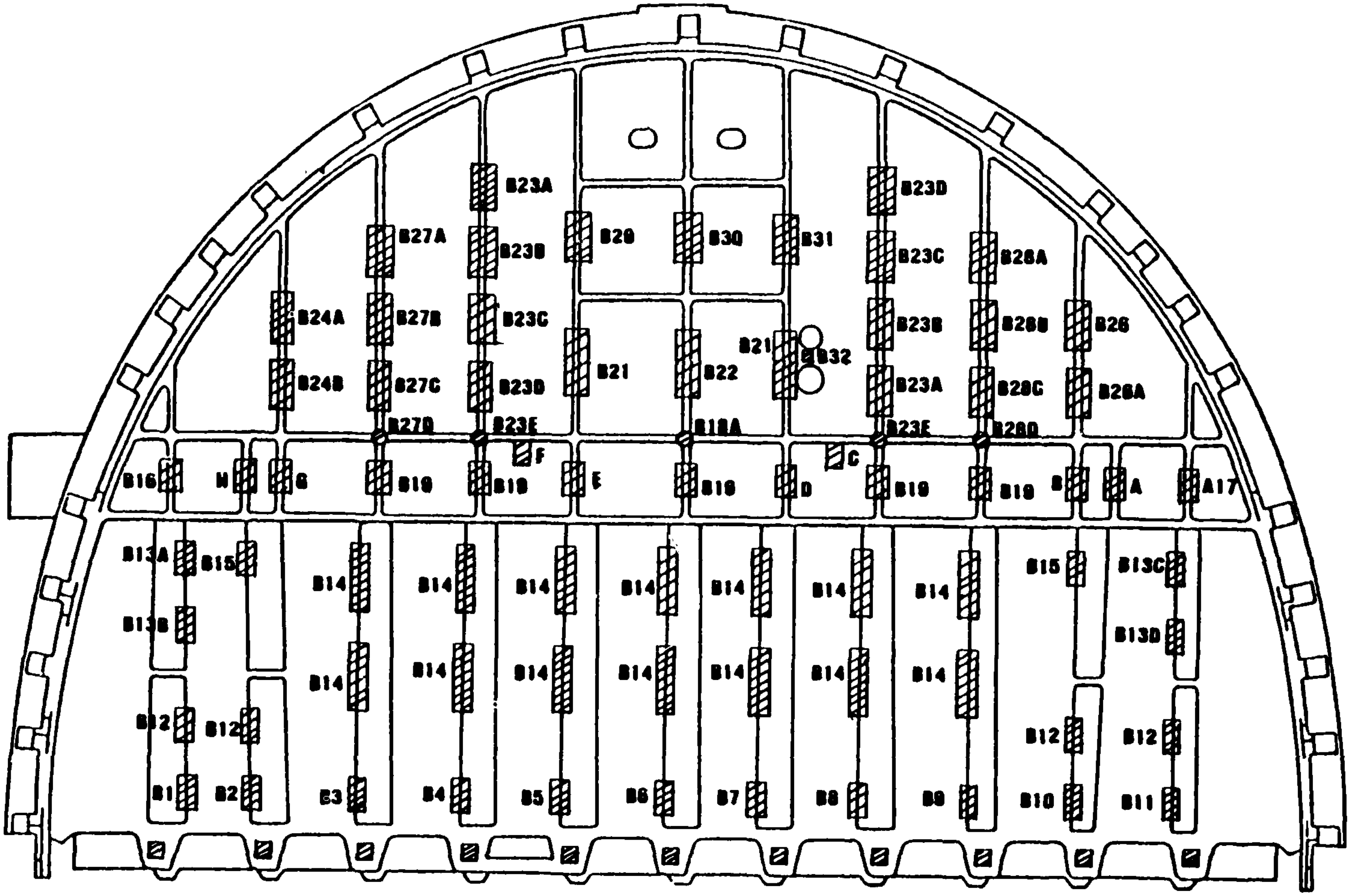


FIGURE 8 STEP GATE LOCATIONS-FWD SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

FIGURE 9 ATTACHMENT OF PADS AT CORRUGATED SECTION

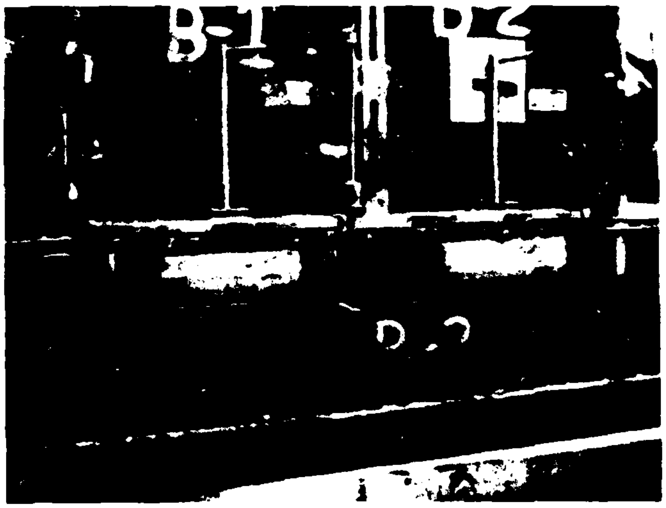


FIGURE 10 NO GAP SHOULD BE PRESENT BETWEEN THE FLASK MACHINED PADS & THE PATTERN STEEL PLATE

- Pin flasks to pattern with guide pins.

  Note: Check to make sure there is no gap between the machined pads on the flasks and the steel plate on the pattern (see Figure 10). If a gap is present, check for loose sand between the flask and pattern. Also check to be sure the machined pads of the flask are in contact with the back surface of the pattern. This step is critical to the alignment of the entire mold.

- Clamp both ends of A1 and B1 backing boards to their respective flasks similar to the one shown in Figure 11.

  Note: Check to be sure the backing board is in contact with the machined pads of the flask.

- Continue to fill molding flasks with AFS 70 sand as described in section 3.3.4.4.
- Remove backing boards after a minimum of 2 hours cure time.
- Check mold surface for any evidence of back draft. If there is any back draft, it must be removed before the next flask is molded or flask A1 and/or B1 will not strip from the pattern.
- Spray exposed surface of the mold with the parting agent specified in section 3.3.2.

3.3.4.3.2 Molding Flasks A2 and B2

- Set in place all chills and step gates contained in molding flasks A2 and B2 (see Figures 5,6,7 and 8). There should be 57 step gates in flask A2 and 45 in flask B2.
- Place 3/8" dia. washers and 5/16"-18 wing nuts on core bolt studs (B2 side only).
- Coat backing boards for A2 and B2 flasks with parting agent. Recoat as required.
- Position backing boards for A2 and B2 flasks. Pin and clamp backing boards to the pattern. Note: Backing board for A2 flask should have attached to it 4 ingate prints on BWL 105 at the intersection of the vertical ribs (see Figure 12).

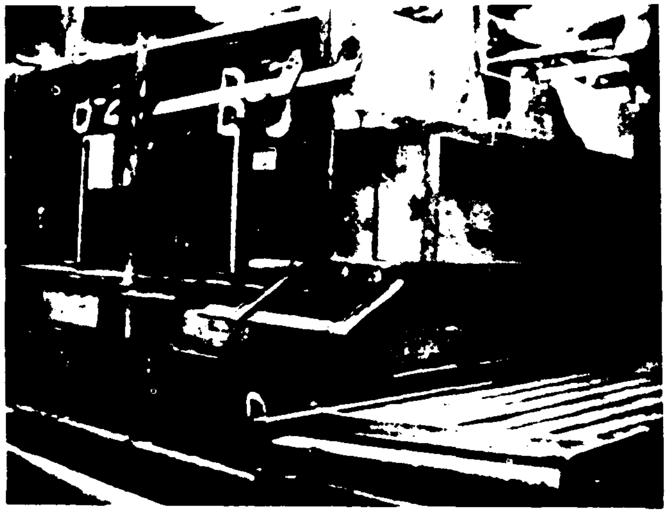


FIGURE 11 CLAMPING A BACKING BOARD TO FLASK B3

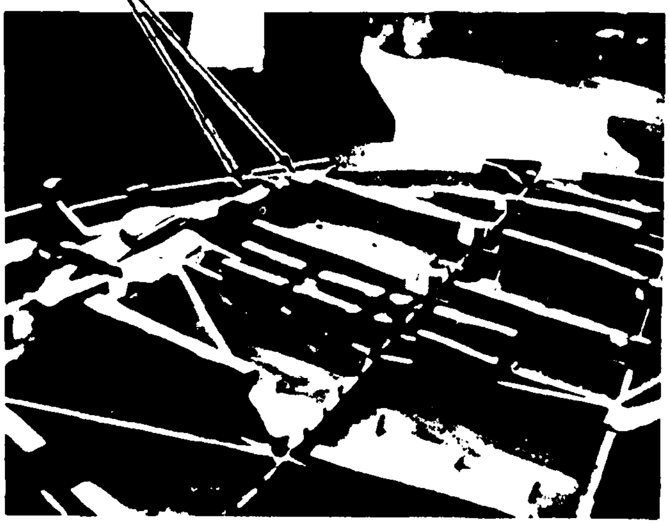


FIGURE 12 LOCATIONS OF IN-GATE ATTACHMENT FOR A2 FLASK BACKING BOARD (ONLY TWO SHOWN)

There also should be a loose print placed between the backing board and the ingates which feed the attach fittings. These prints are needed to make a cavity so a ceramic pad can be inserted during mold assembly.

- o Fill flask with AFS 53 sand as described in section 3.3.4.4.
- o Set sprue cores (-51) in place on both forward and aft patterns.
- o Set flasks A2 (-4) and B2 (-7) in place on aft and forward patterns respectively.
- o Pin flasks to pattern with guide pins. Note: Check to make sure there is no gap between the machined pads in the flasks and the steel plate on the pattern (see Figure 10). If a gap is present, check for loose sand between flask and pattern. Also check to make sure there is no gap between machined pads of flasks A1/A2 and B1/B2 similar to Figure 13 . This step is critical to the alignment of the entire mold.
- o Clamp both ends of A2 and B2 backing boards to their respective flasks in a manner similar to that done on flasks A1 and B1.
- o Continue filling flasks A2 and B2 with AFS 53 silica sand as described in section 3.3.4.4.
- o Remove backing boards after a minimum of 2 hours cure time.
- o Check mold surface for any evidence of back draft. If there is any back draft, it must be removed before the next flask is molded or flask A2 and/or B2 will not strip from the pattern.
- o Spray exposed surface of the mold with the parting agent specified in section 3.3.2.

3.3.4.3.3 Molding Flasks A3 and B3

- o Set in place all chills and step gates contained in molding flasks A3 and B3 (see Figures 5,6,7 and 8). There should be 10 step gates in flask A3 and none in flask B3.
- o Place 3/8" dia. washers and 5/16"-18 wing nuts on core bolt studs (B3 side only).

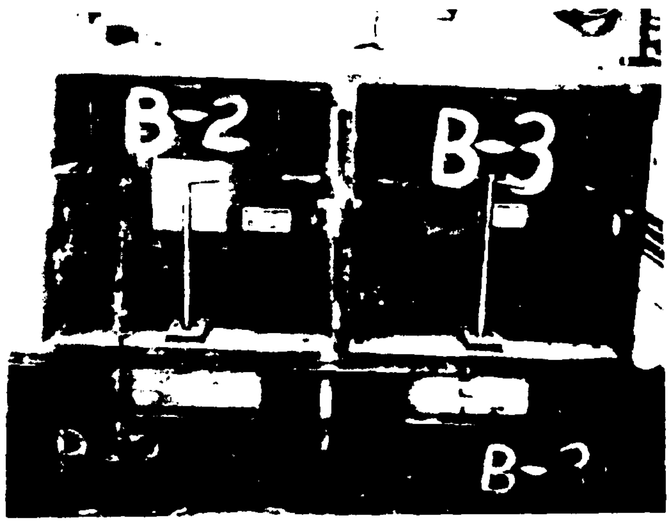
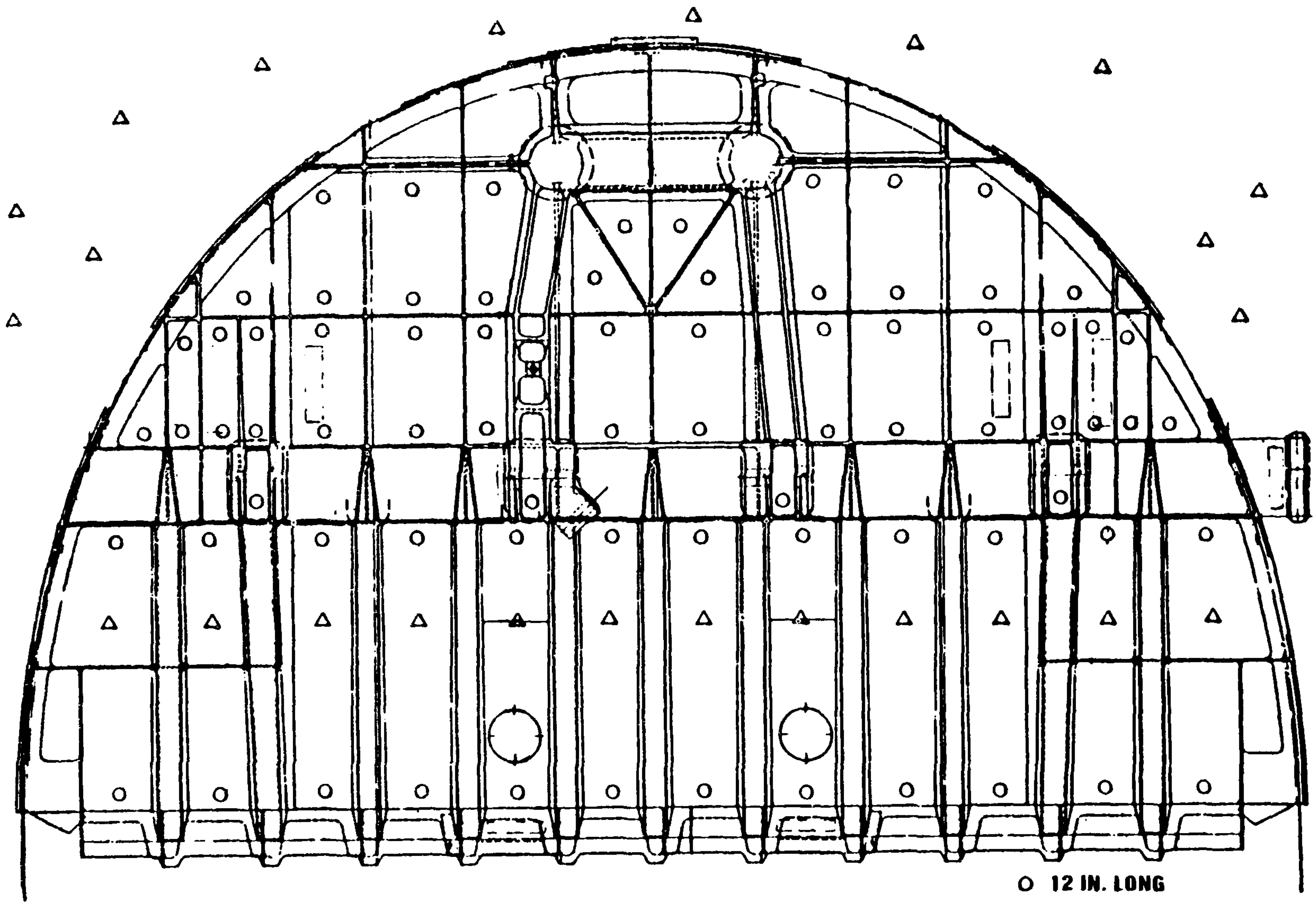


FIGURE 13 NO GAP SHOULD BE PRESENT BETWEEN MACHINED PADS OF ANY TWO FLASKS

- Position flasks A3 (-5) and B3 (-8) in place on aft and forward patterns respectively.
- Pin flasks to pattern with guide pins. Note: Check to make sure there is no gap between the machined pads on the flasks and the steel plate on the pattern (see Figure 10). If a gap is present, check for loose sand between flask and pattern. Also check to make sure there is no gap between the machined pads of flasks A2/A3 and B2/B3.
- Coat backing boards for A3 and B3 flasks with parting agent.
- Position backing boards onto A3 and B3 pattern locations and clamp into place.
- Fill flasks A3 and B3 with AFS 53 silica sand as described in section 3.3.4.4.
- Remove backing boards after a minimum of 2 hours cure time.

3.3.4.4 Filling of Molding Flasks

- Fill sand to the tops of the step gates and strike off surface. Note: Make sure the struck surface is level so metal flow will not be restricted.
- Place gaggers in the sand as required to reinforce the mold. Approximate gagger locations are shown in Figures 14 and 15. Make sure the gaggers in flask A2 and B2 do not interfere with placement of the secondary runner system. Note: Gaggers must be placed approximately as shown; otherwise, the mold may break up when it is stripped.
- When the sand is partially cured (20-30 minutes after mixing), carefully remove all step gates from the sand. Note: Count all step gates and compare with the quantities shown in Figures 7 and 8.
- Place fiberglass screens over all step gate cavities.
- Place thermogard insulating riser sleeves (2½" or 3½" diameter, cut in half longitudinally) over screening material as shown in Figure 16. Note: Make certain all step gate cavities are



21

FIGURE 14 APPROXIMATE GAGGER LOCATIONS, AFT SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

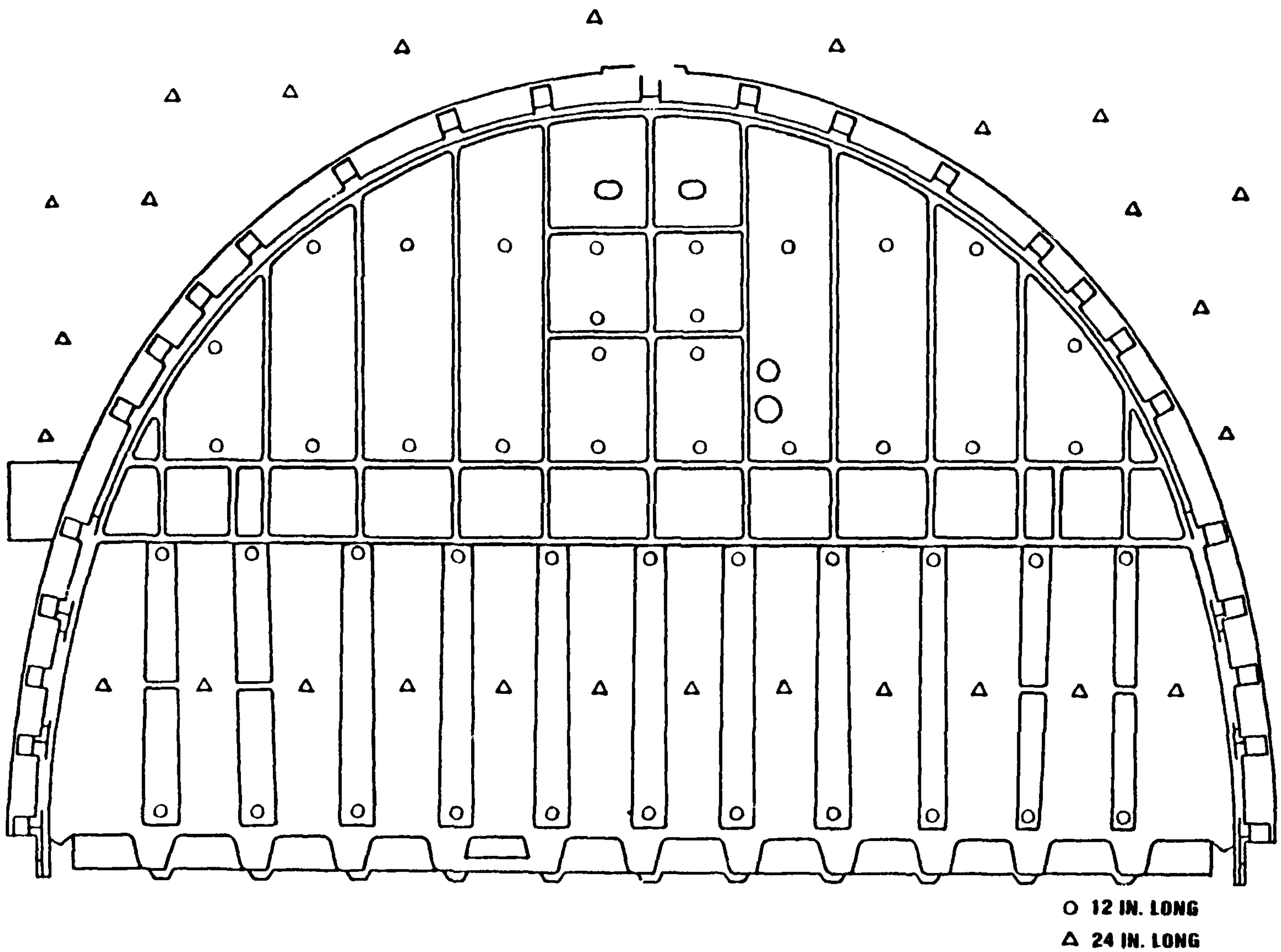


FIGURE 15 APPROXIMATE GAGGER LOCATIONS, FWD SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

FIGURE 16 PLACEMENT OF FIBERGLASS SCREENING MATERIAL & THERMOGARD INSULATING RISER SLEEVES

completely covered.

- Locate AWG 20 electrical wires for metal tracking lights in flasks A1 and B1 as shown in Figures 17 and 18.
- Place a section of fiberglass screen normal to each vertical riser about six inches above mold cavity as shown in Figure 19. The purpose of these screens is to cause a back pressure, forcing the metal to flow into the corrugated sections.
- Place pop-offs at the end of both the secondary and primary runner-systems. Make certain the pop-offs provide a continuous path for gas to escape from the runners to the top of the mold.
- Molding Flasks A1/B1 and A2/B2 only. At this point, set molding flasks in place.
- Molding Flasks A2/B2 only. Place B-1 secondary runner in A2 flask and B-2 secondary runner in B2 flask. The runner halves should be fastened together. Cut out a slot in the middle of a 6 inch section of 2½" dia. thermogard riser sleeves so each one will fit over the ingates on the runners. Set the runners in place and attach them to the appropriate locators on the flasks. Place thermogard riser sleeves over step gate cavities as described above. Fill the molding flasks with sand up to the tops of the runners. Wait until sand is partially cured before removing runners. Remove runners by unfastening the runner from the flask and the two runner halves. Remove the top half of the runner first and then the bottom half. If the two halves weren't aligned properly the bottom half will be difficult to remove. Place steel wool into pouring well of secondary runner systems. Cover the runner cavity with slab cores (See Figure 20).
- Finish filling the molding flasks with sand. At the outboard end of each flask, make a rectangular cavity in the mold (see Figures 21 and 22). Fill these cavities with dry, unbonded sand and cover the cavities with 2" of bonded sand. The preparation of these cavities is to simplify the mold shakeout procedure.

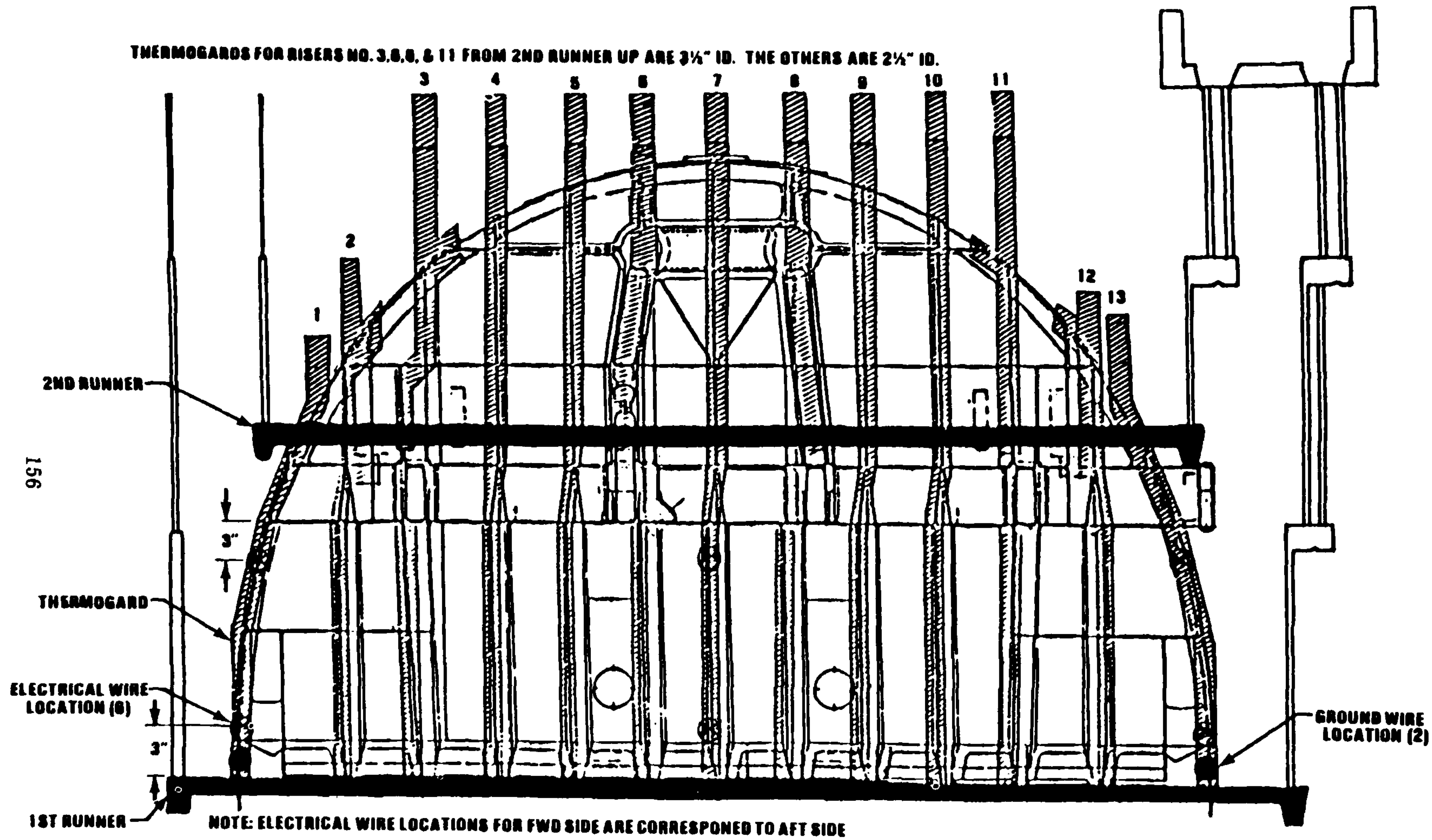


FIGURE 17 ELECTRICAL WIRE LOCATIONS-AFT SIDE, YC-14 STATION 170 BODY BULKHEAD CASTING

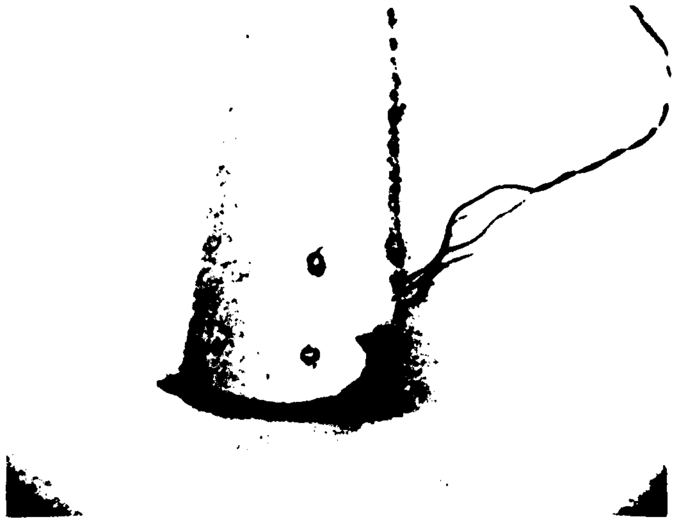


FIGURE 18 INSTALLATION OF ELECTRICAL WIRES IN THERMOGARD SLEEVE

FIGURE 19 PLACEMENT OF FIBERGLASS SCREENS NORMAL TO VERTICAL RISERS

26

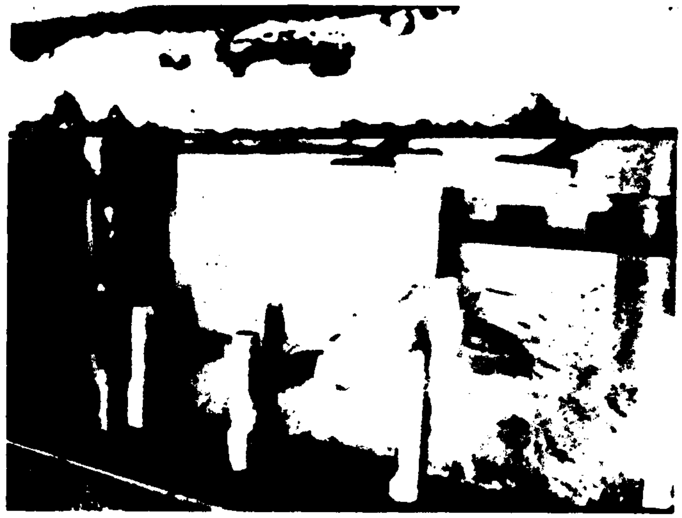


FIGURE 20 PLACEMENT OF SLAB CORES OVER SECONDARY RUNNER

FIGURE 21 SAND CAVITY FOR EASING MOLD SHAKEOUT

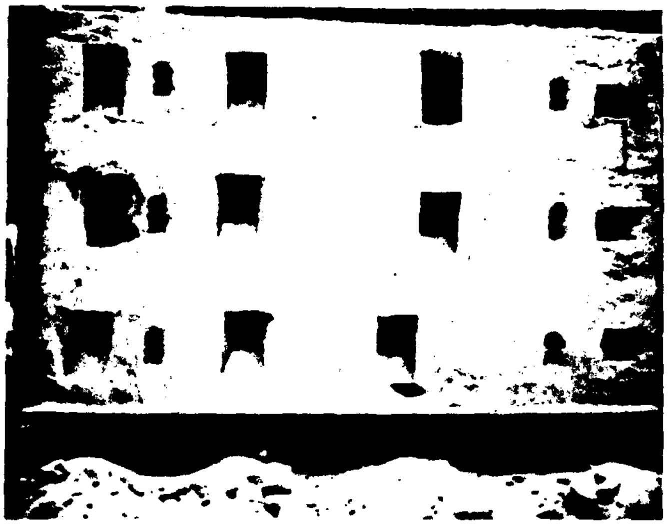


FIGURE 22 LOCATIONS OF MOLD SHAKEOUT CAVITIES

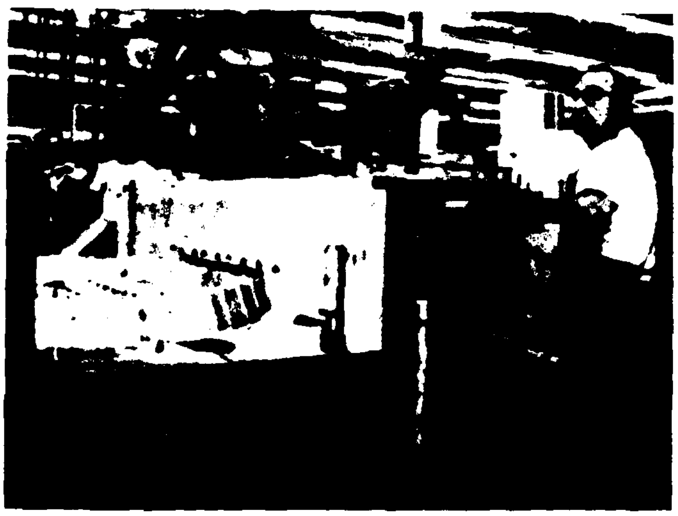


FIGURE 23 ATTACHMENT OF SPREADER BAR, CRANE, & STEEL TRIANGLES FOR FLASK STRIPPING

- o Strike off molding flask.

3.3.5 Flask Stripping and Rotation

- o The sequence of flask removal on each pattern is A1, A2 and A3 and B1, B2 and B3. This sequence for the respective patterns must be adhered to because the flask sides have 2^o draft and will not strip in any other sequence.
- o Attach spreader bar and crane to flask. As the flasks are raised with the hydraulic jacks, take up the slack with the overhead crane, Figure 23. This is a safety measure to prevent damage to the pattern if the jacks do not hold.
- o Molding Flasks A2/B2 and A3/B3 only. Secure two steel triangles, one at each end of the flask to be stripped, Figure 23. These steel supports will prevent movement of the flask into the pattern which would cause pattern damage.
- o Place I beam jacking supports into the rectangular tubes of the flask to be removed.
- o Place a level on the end of each flask to ensure the flask is level during stripping.
- o Using 4 hydraulic jacks, as shown in Figure 24, with a minimum load capacity of 1½ tons each, jack the flask up until the entire flask clears all pattern surfaces by 2 inches minimum. Make sure the guide pins do not bind during stripping. If guide pins bind, lower flask and remove pins. Do not extend the jacks beyond 11 inches. When the jacks are extended 11 inches, block the flasks, release the jacks and raise the jacking stands.
- o Remove the guide pins and lift the flask off the jacks with the overhead crane.
- o Set flask on steel supports with each end of one I beam in the rollover cradle. Attach the spreader bar and crane at location 90^o from original position. Raise crane until flask is rotated (See Figure 25).
- o Set cores as described on section 3.3.6.

FIGURE 24 STRIPPING FLASK WITH FOUR HYDRAULIC JACKS (TWO ON EACH SIDE)

30

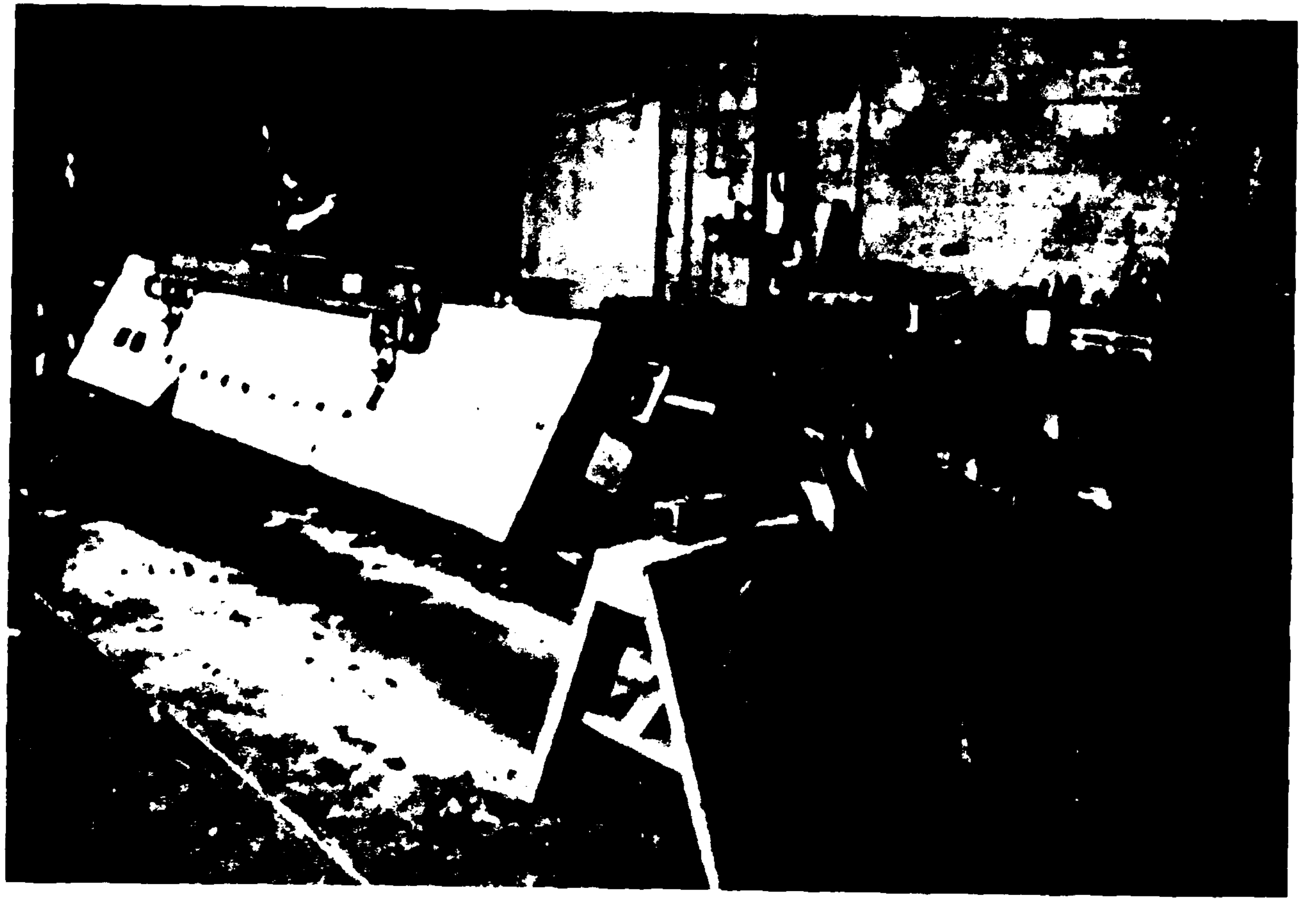


FIGURE 25 ROTATION OF MOLDING FLASK

3.3.6 Core Setting

- Secure cores with bolts. Use 5/16" dia. x 8½" L bolts for cores around the periphery and 5/16" dia. x 9½ L bolts for cores in the corrugated area. Bolts can be made from 5/16" threaded rod cut to length with a 1" OD washer placed between two nuts at one end of the rod.
- Fill in all bolt holes with sand mixed with sodium silicate - CO_2 and smooth the surface.
- After placement of cores, check to be certain they are aligned properly. If a core is misaligned, investigate the problem until the reason for misalignment is determined and corrected. A misaligned core will jeopardize the quality of the entire casting.
- After the cores have been set in place, in each flask, drill 1/8" dia. vent holes approximately 3" apart in all ribs and in the center of all webs which are .100" thick. The base of the vent hole must not exceed 3/16" dia.

3.3.6.1 Base Flask

- Set in place 5 base cores (1A, 2B's, 1C, 1D) in the following sequence B,B,A,C,D. The core locations are shown in Figure 26. Bolting of these cores is optional since they will not move. If bolts are not used, filling the bolt holes with sand is still needed.

3.3.6.2 Flask A1

- No cores go into flask A1.
- Scratch vent lines, approximately 4 inches apart, off the shelf at WL 130. Remove all pads which were attached in Section 3.3.4.3.1.
- Assemble flask A1 as outlined in section 3.3.7.

3.3.6.3 Flask B1

- Set eleven corrugated cores (1 LR, 1RR, 2S's, 5T's, 1U, 1V) at the locations shown in Figure 26. These cores may be placed in

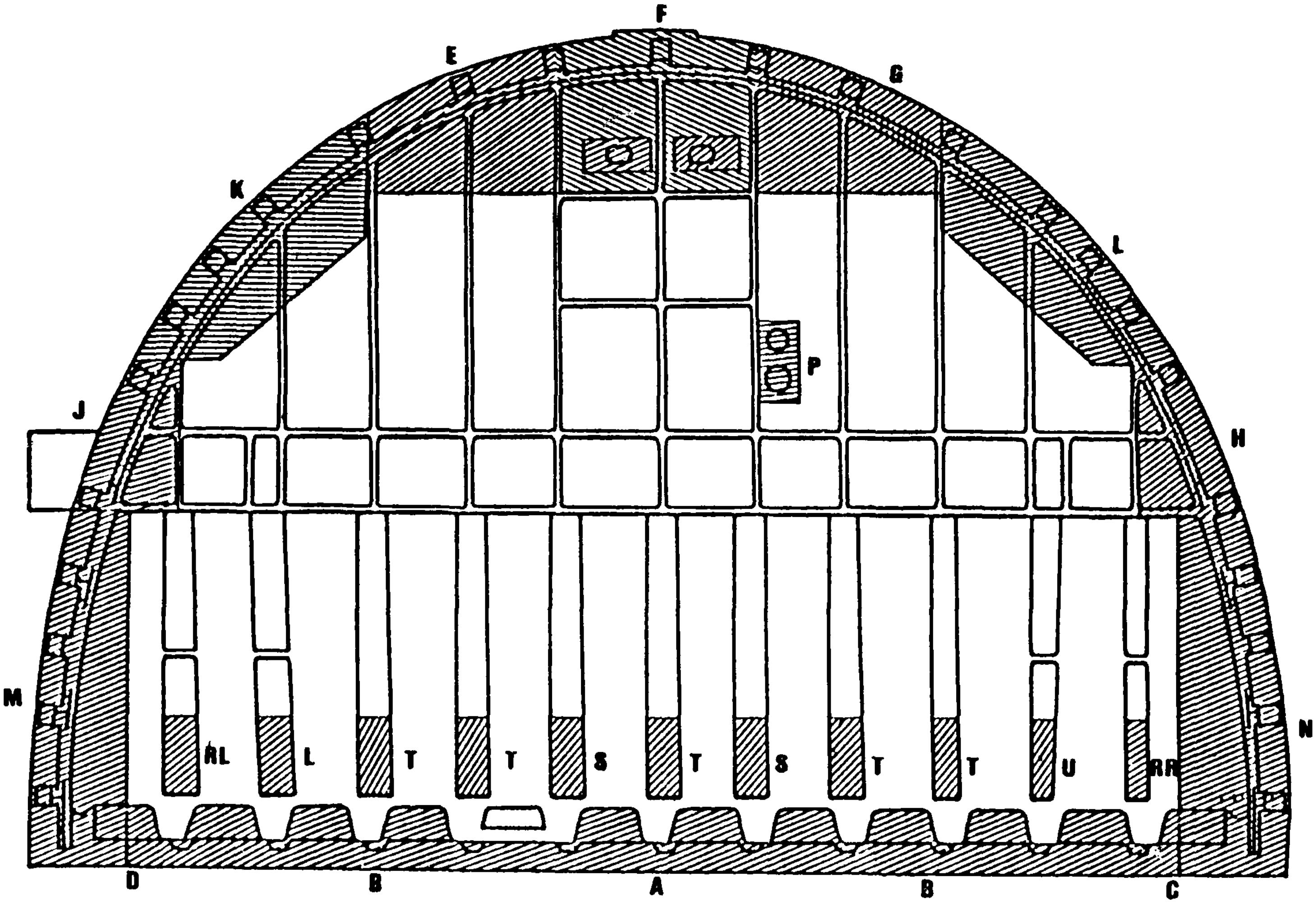


FIGURE 26 CORE LOCATIONS-FWD SIDE YC-14 STATION 170
BULKHEAD CASTING

any sequence. Make sure left hand R goes at location LR and right hand R goes at location RR.

- Set two periphery cores (M,N) in any sequence.
- Assemble flask B1 as outlined in section 3.3.7.

3.3.6.4 Flask A2

- Set core (Q) in place at the location shown in Figure 27.
- Set torque box cores (O-1, and O-2) in place just before stacking flask B3 on B2 as described in section 3.3.7.
- Drill and file a 2" wide step gate to each of the ribs on the shelves at WL 130 (see Figure 28). Make sure these ingates are connected to the 3½" dia. vertical risers.
- Assemble flask A2 as outlined in section 3.3.7.

3.3.6.5 Flask B2

- Set four periphery areas (H, J, K, L) in place, in the following sequence: H, K, J, L. The core locations are shown in Figure 26.
- Set core (P) in place.
- As described in section 3.3.7 the three periphery cores (E,F,G) must be set on top of flask B2 while flask B3 is being set in place.
- Assemble flask B2 as outlined in section 3.3.7.

3.3.6.6 Flask A3

- Torque box core (O-2) is supposed to go into flask A3. However, it is easier to place it on top of O-1 in flask A2 and then set flask A3 on top of A2. This procedure is outlined in section 3.3.7.
- Assemble flask A3 as described in section 3.3.7.

3.3.6.7 Flask B3

- The three periphery cores (E, F, G) which are to be set in flask B3 are to be set on top of flask B2 after B2 is assembled.

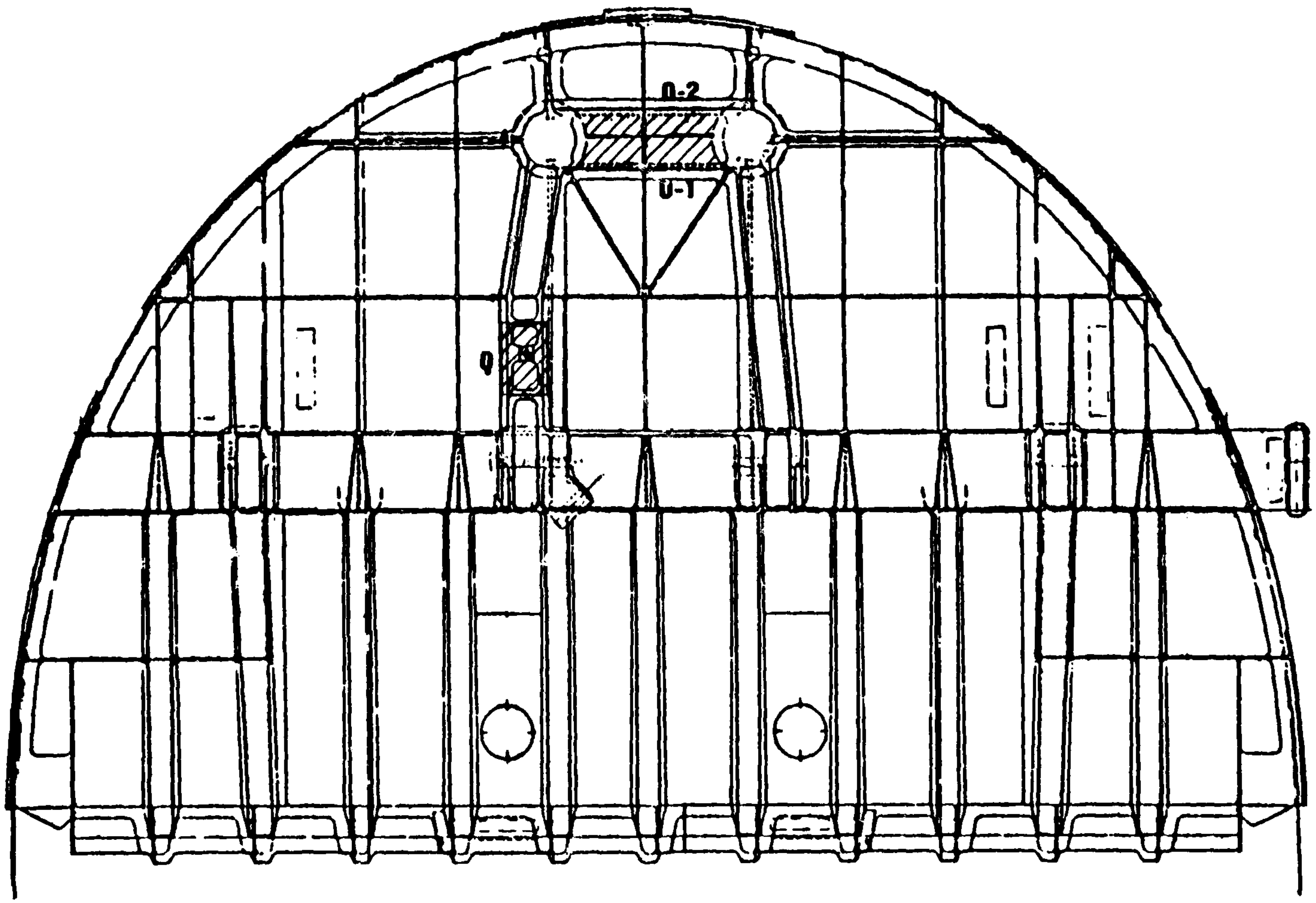


FIGURE 27 CORE LOCATIONS-AFT SIDE YC-14 STATION 170 BODY BULKHEAD CASTING

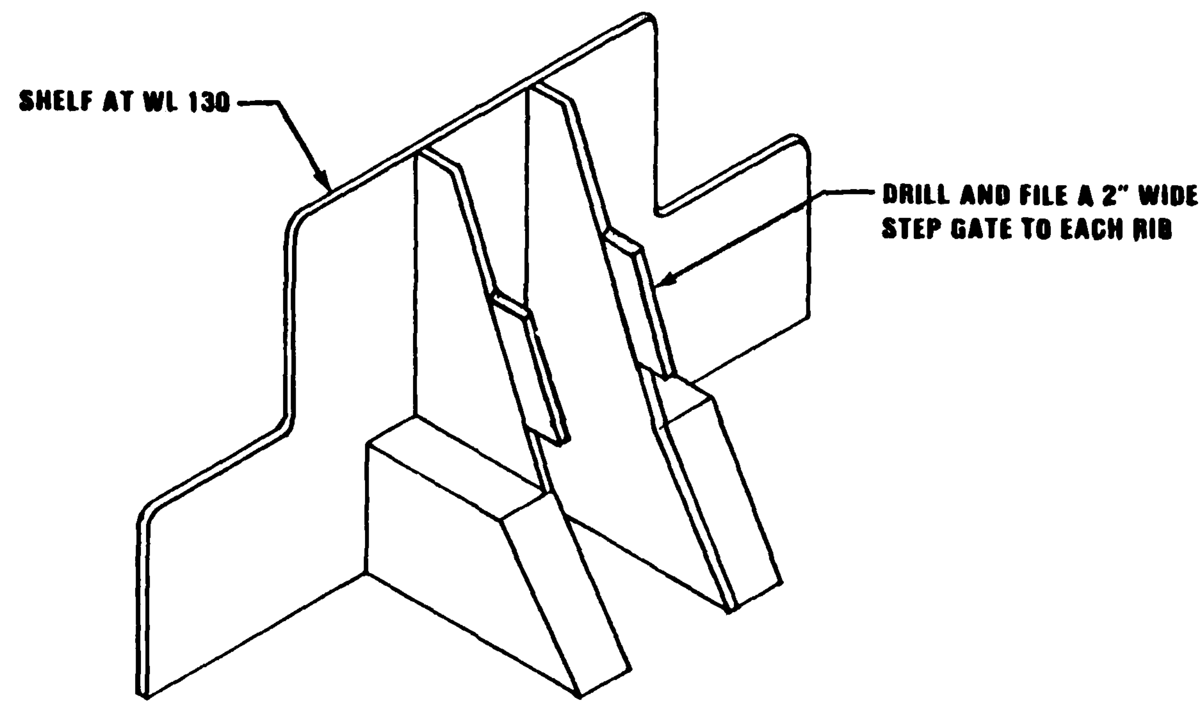


FIGURE 28 STEP GATE LOCATIONS OF SHELVES AT WL 130

This procedure is described in section 3.3.7.

o Assemble flask B3 as described in section 3.3.7.

3.3.7 Mold Assembly

o Prior to mold assembly apply two thin coats of Ashland moldcote 3 to surface of flasks A1 and B1 and the web areas of flask A2 and B2. Also apply an amorphous carbon coating (.001 inch thick) to all mold surfaces.

o Place flask B1 on base flask with guide pins in place.

o Secure guide bar to flask B1, Figure 29. Shim guide bar .010 inch on each side.

o Lower flask A1 to approximately one inch above base flask and carefully move flask A1 into B1. Put guide pins in place and lower flask A1 onto base flask. Check thickness of corrugated sections with .100" feeler gauge. Repeat this step as necessary to the proper wall thickness. This step is extremely important for proper alignment of the other flasks.

o Place flask B2 on top of flask B1 with guide pins in place.

o Place flask A2 on top of flask A1 with guide pins in place.

o Set three periphery cores (E, F, G) on top of flask B2 in the locations shown in Figure 26. Check to make sure cores E, F and G are properly aligned. This can be done by placing a straight edge across the cores surface and check to see if it matches the cores surface, Figure 30. If the cores are properly aligned, bolt cores E, F and G in place.

Note: Take precautions not to drop any foreign material into mold cavity.

o Place steel wool in the sprue wells and place molders clay around the sprue openings on top of flasks A2 and B2.

o Carefully lower flasks B3 and A3 onto flasks B2 and A2 respectively with guide pins in place.

o Secure flasks A1/B1, A2/ B2, A3/B3 together on both ends with 1/2" bolts

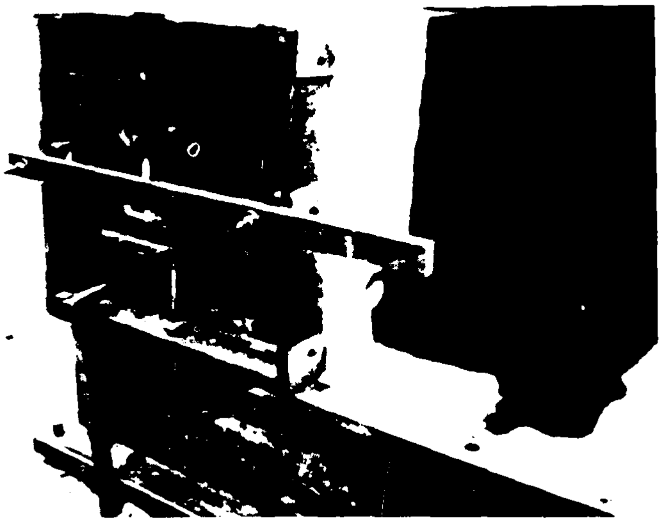


FIGURE 29 ATTACHMENT OF GUIDING BAR TO B1 FLASK

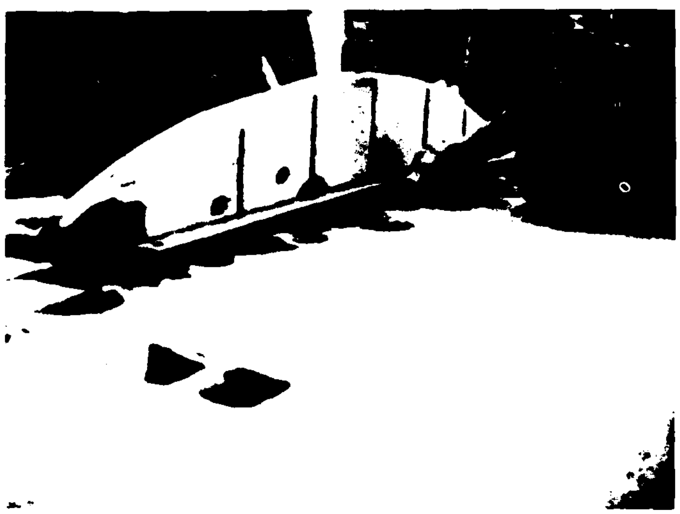


FIGURE 30 CHECKING PROPER ALIGNMENT OF E, F, & G CORES

- o Fill all gaps between flasks with sand mixed with sodium silicate-CO_2 binder to prevent any metal runout.
- o Place molders clay around the sprue openings on top of flasks A3 and B3. Set in places pouring basins (-52) with pouring plugs (-99). Be sure the basins are properly aligned over the sprue openings.
- o Hook up all the electrical wires to the light indicator as shown in Figure 31 and then place it on top of the mold for easy visibility.
- o As soon as the mold is assembled, cover all the openings located on top of the mold until just prior to pouring.
- o Assemble scaffolding around the mold. The two 10' pouring platforms should be placed perpendicular to the ends of the mold. Also the 7' observation platform should be placed parallel to one of the sides. Caution: Make sure the guard rails are up and there are no gaps between the floor sections. Instruct pouring personnel as to the safest and quickest method of egress in case of a pouring problem.
- o Prepare metal for pouring as outlined in section 3.4.
- o During metal preparation, prepare mold for pouring as outlined in section 3.5.

3.4 Mold Preparation for Pouring

- o Seal off the pop-offs and all the risers except the middle riser of the A and B flasks.
- o Pump argon gas into the mold through the two open risers. This should be done 2-3 hours prior to pouring. Pumping time should be approximately 2-2½ hours with a light flow of gas. The temperature of the argon which enters the mold should be a minimum of 70°F, maximum of 120°F.

3.5 Metal Preparation

3.5.1 Material Storage

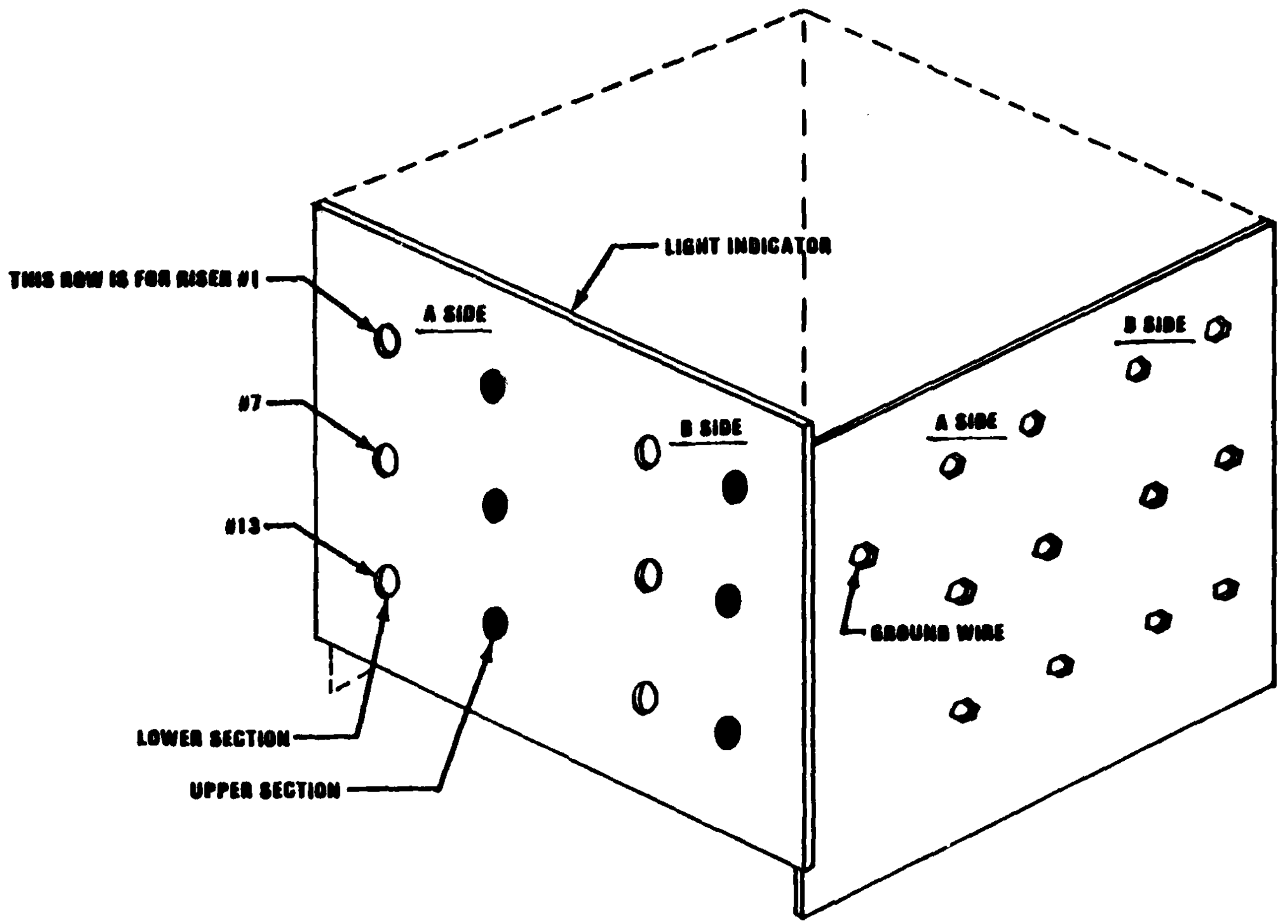


FIGURE 31 LIGHT INDICATOR ELECTRICAL WIRES HOOK-UP

- When storing metal ingots, protectively cover with polyehtylene to prevent contamination.

3.5.2 Metal Melting

3.5.2.1 Furnace Charging

- The casting requires approximately 1700 pounds of A357. Charge two 1000-lb.capacity furnaces, each with 960 lbs. of B356.2 and adjust to A357 per M-XXXX or charge furnaces with A357 per M-XXXX.

3.5.2.2 Holding Temperature

- Hold metal at 1250-1300^{o}F prior to degassing.
- Check chemistry as outlined in section 3.5.2.5.

3.5.2.3 Degassing

- Degas metal at 1300-1325^{o}F for 40 minutes with a gas mixture of 90-95% nitrogen and 5-10% chlorine.
- Flow rate should be adjusted so the rolling action of the metal does not break the oxide layer on the surface of the metal.
- After degassing, wait 15 minutes, skim the metal surface and check the gas content per section 3.5.2.4.

3.5.2.4 Gas Check

- Remove approximately three ounces of molten aluminum with a heated crucible and place it in a vacuum freeze chamber, similar to the one shown in Figure 32.
- Let molten metal solidify under 27 $\pm$ 1 inch of mercury for 8 minutes.
- Observe the surface of molten metal during solidification. If bubbles break at the surface during the initial stages of solidification, this indicates oxides are present in the metal. If bubbles break the surface during the final stages of solidification, there is hydrogen gas present in the metal. Double

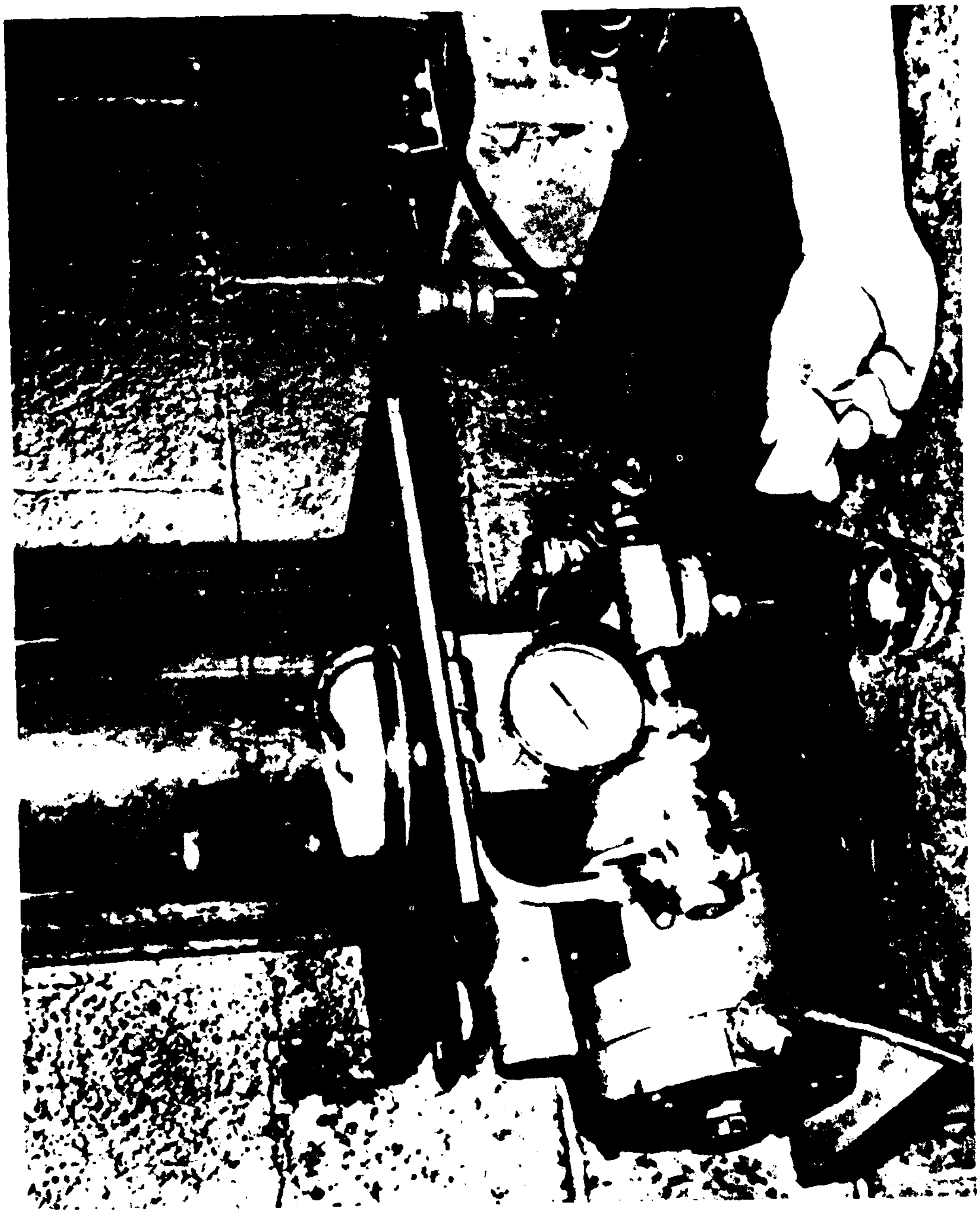


FIGURE 32 VACUUM FREEZE CHAMBER FOR GAS CHECK

check this method of gas determination by sectioning the specimen with a sharp, fine tooth saw blade and examine under 5X magnification for any pinhole porosity.

- If bubbles form during solidification or pinhole porosity is present when specimen is sectioned, too much gas is present. Degas again for 20-30 minutes and repeat gas check.
- Immediately after obtaining a good gas sample, place a cover on top of the furnace opening to minimize absorption of hydrogen gas. Provide a gentle flow of argon gas over the molten metal through the furnace spout (This step is optional).
- If metal is not poured within 2 hours of final gas check, perform another gas check to verify quality of metal.

3.5.2.5 Chemical Analysis

- Prior to degassing adjust magnesium content to .60-.65% and beryllium content to .065-.070%.
- Determine chemistry of melt by spectrographic analysis after final degassing procedure.
- If chemistry of the melt does not satisfy the requirement of M-XXXX, adjust chemistry and repeat the degassing procedures.
- Record results of chemical analysis and metal additions.

3.5.2.6 Metal Heat Up

- After satisfying the degassing requirements and chemical analysis of sections 3.5.2.4 and 3.5.2.5 respectively, begin to heat metal up to the pouring off temperature.
- Heat the metal in both furnaces to 1480 $\pm$ 10°F maintaining the same heat up rate in both furnaces. Heat up time should not exceed 1½ hours.
- When metal has reached 1480 $\pm$ 10°F, as indicated by temperature measurement of the melt itself, follow ladle filling procedures outlined in section 3.6.2.

3.6 Ladle Fill

3.6.1 Ladle Preheat

- o Apply graphite wash to two 1000-lb. capacity ladles prior to preheating (Optional).
- o Place insulated covers over ladles to insure uniform heating of the refractory lining.
- o Preheat ladles to 1600 $\pm$ 50^{o}F with a natural gas fired lance or by electrical means.
- o Ladle lining temperature must not drop below 1300^{o}F before filling with molten metal.

3.6.2 Ladle Filling

- o When temperature reaches the 1480 $\pm$ 10^{o}F pour-off temperature as described in section 3.5.2.6, fill each ladle with 900 lbs. of metal.
- o Immediately prior to pour-off remove the argon lance and the furnace cover from the furnace. Move the preheated ladle to the furnace as fast as possible to minimize heat loss from the ladle.
- o Pour the metal from the furnace to the ladle in a uniform stream without breaking the oxide layer which forms on the surface. Maintain a maximum distance of two inches between the top edge of the ladle and the pouring lip of the furnace.
- o Continuously adjust the angle of metal flow into the ladle to provide a minimum of turbulence during ladle fill.
- o Remove a sample of molten metal from each ladle for spectrographic analysis.
- o Transfer the two ladles to the mold and skim off the surface dross.
- o Move the ladles into their proper pouring positions.
- o Check pouring temperature as outlined in section 3.6.3.

3.6.3 Pouring Temperature Check

- o Using a hand held pyrometer, check the metal temperature in each ladle.
- o Begin the pour when the temperature of either ladle reaches 1440^{o}F.
- o If for some reason the temperature of one or both of the ladles is below 1430^{o}F when checked at the mold, call off the pour and return the metal to the furnace. Repeat the procedures outlined in sections 3.5.2.2 through 3.6.3.

3.7 Pouring

- o Simultaneously transfer the metal from each ladle into their respective pouring basin. Fill each basin to within one inch of the top and maintain this level throughout the pour. Then simultaneously remove the outboard plug in each basin. Remove the other two plugs at the same time when either one of the red tracking lights is activated or 25 seconds has past since pulling the first plug, whichever occurs first.
- o The pouring operation will take approximately 80-85 seconds from the time the first plug is removed.
- o During the pouring operation, continuously adjust the angle of metal flow into pouring basin to provide a minimum of metal turbulence. Maintain a maximum distance of 3 inches from the ladle spout to the top of the pouring basin.
- o Stop pouring as soon as metal is observed 6 inches from the top of the risers.

3.8 Mold Shakeout

- o Immediately after pouring, break up the solidifying metal on top of the mold.
- o Remove the pouring basins.
- o Remove sand from cavities shown in Figure 22.

- Begin flask removal no sooner than 1½ hour after pouring. Flask removal sequence is: B3, A3, B2, A2, B1, A1.
  Caution: Before removing flask A1, remove the sand from around the shelves at WL 130.

- Remove the sand from the casting by sandblasting the mold sand to within 1/4" of the casting and then manually remove the sand. Be careful not to damage the casting during shakeout.

3.9 Casting Cleanup

- Rough trim all step gates and runners from casting with reciprocating saw or by any other technique which will not damage the casting.

- Clean casting to net dimensions per 162-00017 as required.

3.10 Inspection

- Maintain complete records of inspection results. Locate and identify, on appropriate sketches, all defects or other discrepancies found by visual, dimensional and NDE inspections. These records may be attached to the shop orders or entered in an inspection log book.

3.10.1 Visual

- Visually inspect the casting for casting defects such as cold shuts, misruns, surface porosity, mossing, etc.

- Lable defect areas with a non-washable means of marking.

- Fit the casting to check fixture NCMF 162-00018 to assure dimensional accuracy.

3.10.2 DAS Measurement

- Conduct dendritic arm spacing measurement per MIL-Y-XXXX. (See Technical Bulletin No. 7).

- Examine at locations shown on casting drawing 162-00017.

3.10.3 X-ray

3.10.3.1 Radiographic Procedures

- o Radiography shall conform to MIL-C-6021B and MIL-STD453.
- o Radiographic coverage shall be 100% of the inspectable areas.
- o Use fine grain film, Type M or equivalent.

3.10.3.2 Required Inspections

- o Inspect trimmed and cleaned casting.
- o Locally inspect completed weld repairs.

3.10.3.3 Acceptance Criteria

- o Limits of acceptable imperfections shall be in accordance with MIL-A-XXXX, "Aluminum Alloy A357 Castings, Primary Aircraft Structure".

3.10.3.4 Records

- o Radiographic film placements will be located and identified on appropriate sketches of the casting.
- o X-ray reports shall include the radiographic technique descriptions, interpretation results and locations of rejected areas.
- o All films, including those of repaired areas, shall be properly identified and stored with the x-ray report and identification sketches.

3.10.4 Penetrant Inspection

3.10.4.1 Etch

- o Chemically remove 0.0002"-0.0004" from all sawed, ground or blasted surfaces.

3.10.4.2 Penetrant Inspection Materials

- o Fluorescent penetrants only.
- o Sensitivity equivalent to Group V per MIL-L-25135 (ZL-15B is considered appropriate).

- o Water washable penetrant preferred - developer not required.

3.10.4.3 Required Inspections - per MIL-I-6866, "Inspection, Penetrant, Method of".

- o Inspect trimmed and cleaned castings.
- o Locally inspect completed weld repairs.
- o Inspect finish machined casting.

3.10.4.4 Acceptance Criteria

- o Reject open shrinkage cavities, cracks, cold shuts, laps, imbedded foreign materials.

3.10.4.5 Records

- o Complete records will be retained of all inspections, including rejections and re-inspections of repairs.

3.11 Weld Correction

- o Correct imperfections detected during visual, x-ray and penetrant inspection per W-XXXX and the weld correction procedures outlined in Section 3.12.
- o X-ray all weld corrected areas per Section 3.10.3.
- o Penetrant all weld corrected areas per Section 3.10.4.

3.12 Weld Correction of Imperfections; Procedures for A357 Aluminum Sand Castings.

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3.12.1 Application Note

The information contained herein is intended to provide a general guideline for shop personnel performing weld correction of typical aluminum sand casting imperfections. However, in practice, each casting imperfection must be evaluated separately and the detail welding procedures altered to suit the specific application.

In addition, the practicality of restoring any given casting by weld correction requires the careful consideration of such factors as the number, size, and location of individual imperfections, working access, distortion produced by weld shrinkage, weld restraint conditions, and the rework and inspection costs associated with weld correction.

In general, the welding procedures and techniques required to perform weld correction of A357 aluminum sand castings are identical to those commonly employed for weldable wrought alloys. Experience has demonstrated that high-quality weld corrections can be consistently produced by employing reasonable care and standard industry practices.

3.12.2 Typical Casting Imperfections

3.12.2.1 Surface Imperfections

Typical surface imperfections include porosity, voids, tears, cold shuts, and sand entrapment. To correct surface imperfections, it is usually advisable to mechanically remove the imperfection and a minimal amount of surrounding material to produce a smooth, shallow cavity in sound base metal. The cavity is subsequently filled with A357 filler metal during a follow-on welding operation.

3.12.2.2 Internal Imperfections

Internal casting imperfections, such as porosity, voids, and inclusions, are usually detected by radiographic and/or ultrasonic inspection methods. The area containing the imperfection is usually denoted on the part or the X-ray film by the Quality Control technician. Internal imperfections are corrected by mechanically removing the imperfection and enough surrounding material to provide adequate welding access and a groove configuration that will produce adequate sidewall fusion. In some cases, it may be advisable to accomplish the correction from both sides of the part. The welding groove configuration, produced in one or both sides of the part, is filled with A357 filler material in one or more passes during a subsequent welding operation.

3.12.2.3 Misruns

Misruns usually appear as holes or voids completely through the part. These imperfections may occur at a part edge inside the part periphery. Correction of a misrun is accomplished by backing up the void area with a copper plate and filling the void area with A357 filler metal during a subsequent welding operation. The edges of the weld deposit are usually remelted from the reverse side of the part to complete the correction.

3.12.2.4 Cracks

Cracks, detected by penetrant, radiographic, or ultrasonic inspection methods, are also correctable casting imperfections.

The corrective procedure usually involves drilling a small "crack stopper" hole through the part at each end of the crack, grooving the part from one side, and filling with A357 weld filler metal. The part is subsequently grooved from the reverse side into sound weld metal and welded again with the addition of A357 filler material.

3.12.3 Preweld Preparation

3.12.3.1 Equipment

Preweld preparation for weld correction is usually accomplished using manually held, air-driven equipment. Although both are used, the in-line type of air grinder is smaller, lighter, and more maneuverable than a pistol-grip-type drill motor. The air grinder rotational speed is also better suited to the cutters used for preweld metal removal. With either type, exercise care so that lubricating oil from the motor geartrain or air exhaust does not contaminate the weld area.

3.12.3.2 Cutters

A multi-toothed, full radius, Woodruff keyseat cutter is best suited for removal of casting imperfections prior to weld correction. Cutter sizes from 1 to 1-1/2 inches in diameter and widths of 3/16 and 1/4 inch are the most useful for general-purpose work. For best results, use only sharp cutters.

For cutter sharpening or regrinding, specify the following information:

Land width - 0.015 inch
Positive rake angle - 3 degrees
Clearance angle - 8 degrees

3.12.3.3 Groove Preparation

Carefully examine the area to be prepared for weld correction and the X-ray film. Correct orientation and alignment of the X-ray film is especially important. Be particularly cautious if the

imperfection is not visible on the surface.

Select a sharp cutter suited to the size and location of the area containing the imperfection. Use a shallow, conventional cut to rough out the cavity. This technique provides good control and minimizes the chance of cutter skidding. Work slowly and carefully. Never remove more material than is necessary to remove the imperfection.

To prevent the adherence and build-up of aluminum material on the face of the cutter teeth, pass the cutter lightly across a block of clean paraffin prior to making the cut. Experience has demonstrated that no weld apparent contamination results if the paraffin is used very sparingly.

The ends and sides of the cavity must be sloped outwards to prevent premature melt-down during welding. From a line perpendicular to the part surface, the cavity walls should slope approximately 15 degrees; the cavity ends should slope at least 45 degrees, Figure 33.

To complete the cavity and provide a suitable surface finish for welding, use a light, climb cut with the drive motor firmly held. The cavity smoothness should be from 32 to 64 RHR with no sharp ridges or tool marks evident.

Cavity depth should be limited to approximately 50% of the part thickness. If the imperfection extends into the lower half of the material thickness, groove out and weld from one side and then turn the part over and repeat the operations on the opposite side. When preparing the second side, remove sufficient material so that the bottom of the cavity is located in sound weld metal.

3.12.4 Preweld Cleaning

The quality of weld corrections is largely dependent upon the cleanliness of the area of the part to be welded. The part surfaces to be melted and the adjacent base metal must be free of inclusions, entrapped sand, dirt, oil, grease and other contaminants, if high-quality weld corrections are to be produced consistentlv.

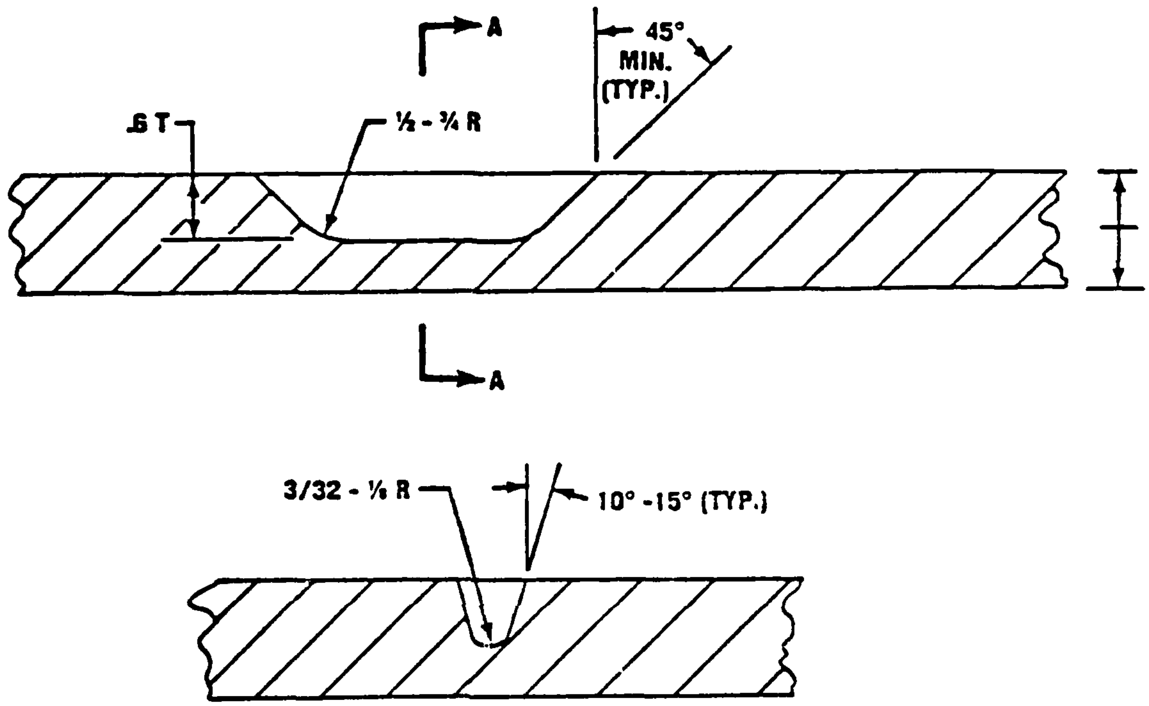

FIGURE 33 TYPICAL GROOVE CONFIGURATION FOR WELD CORRECTION

Solvent cleaning with acetone or methyl ethyl ketone (MEK) is an effective means of removing oily surface contaminants prior to welding. Tilt the part to promote drainage and flush the weld area with a small quantity of either solvent, preferably dispensed from a squirt bottle.

Unless absolutely necessary, avoid wiping the weld area after solvent cleaning. The roughness of the casting surface may cause fuzz, lint, or other particles from the wiper to be deposited in the weld area.

Blow off the weld area with clean, dry filtered air or inert gas to remove metal chips, dust, etc. and evaporate excess solvent. Do not use unfiltered shop air.

3.12.5 Welding Considerations

3.12.5.1 Welding Process Selection

Weld correction of casting imperfections can be successfully accomplished by Gas Tungsten Arc Welding (GTAW) in the Alternating Current (AC) or Direct Current (DC) modes or by the Gas Metal Arc Welding (GMAW) process. The process selection is dependent upon such factors as material thickness, available welding equipment, and availability of suitable weld filler material. However, for general usage, the GTAW process in the AC and DC modes is recommended.

GTAW-AC is usually used for single-side corrections in materials up to 1/8 inch thick without a prepared weld cavity and up to 1/4 inch with a cavity. Thicknesses up to 3/8 inch can be welded successfully using GTAW-AC by grooving and welding both sides. The GTAW-AC mode provides excellent cathodic surface cleaning and good visibility due to the high arc intensity. However, the weld penetration tends to be wide and shallow.

The GTAW-DC mode is used for heavier material sections and produces deep, narrow weld penetration. Because the DC mode produces a small, concentrated arc, the welding visibility is limited and

further restricted by the presence of soot-like surface deposits commonly encountered when using helium-rich gas mixtures.

3.12.5.2 Welding Equipment

Although many conventional, commercially available, manual AC/DC GTAW power sources can be used to produce acceptable quality weld corrections, consistently better results can be obtained using solid state, square wave, variable polarity duty cycle equipment, such as the Syncrowave 300, built by the Miller Electric Company, Appleton, WI.

During test welding in the AC mode, such as a power source completely eliminated the problem of tungsten spitting and produced a substantial reduction in the incidence of porosity in the weld deposit. This equipment also performed well in the DC mode, providing excellent arc stability and smooth weld tailouts.

The power source was operated in the maximum unbalanced polarity duty cycle condition which provided approximately 70% of the time in the straight polarity (electrode negative) mode. This mode promotes increased weld penetration while retaining the AC cathodic cleaning benefits.

3.12.5.3 Preheating

Preheating the casting prior to performing a weld correction is sometimes used to minimize the local thermal gradients and thermal stresses produced by welding. This technique is also used to minimize the effect of different material thicknesses and locally thickened areas such as pad-ups, busses, stiffeners, etc. However, since A357 does not appear to be a crack-prone material, preheating will probably not be required, except under unusual circumstances.

If employed, preheat the casting as uniformly as possible using a heat source that does not contaminate the weld area. Oven heating is the most desirable method because the whole part becomes uniformly heated; however, some parts may be too large for available ovens.

Flame heating is an acceptable preheating method, providing that a soot-free flame is used and the heat is not concentrated in a small local area. Although hydrocarbon fuel gases can be used, a more efficient and contaminant-free heat source is provided by an oxy-hydrogen flame.

Regardless of the heating method employed, the casting should be preheated in the range of 250-300°F, to prevent moisture condensation. The casting temperature can be checked with a contact pyrometer, temperature-indicating crayon, or other suitable means.

Under normal circumstances, controlled or artificial cooling of weld-corrected A357 castings is not required. Natural cooling in still air is usually adequate. Cooling of the base metal between multiple weld passes is not usually required unless the base metal temperature exceeds 500°F.

3.12.5.4 Shielding Gases

The tungsten electrode, weld puddle, and adjacent base metal are protected from atmospheric contaimination during and immediately after welding by providing a uniform flow of high-purity inert gas through the welding torch. Where space permits, the welding torch should be equipped with a gas lens accessory to collimate the gas flow and minimize turbulence. Underbead shielding of welds in A357 aluminum castings is not required.

For GTAW-AC welding of A357 aluminum, inert gas mixtures containing 10-15 cfh argon + 4-5 cfh helium provide adequate shielding and arc stabilization. GTA welding in the DC mode is done using pure helium gas at 40-60 cfh.

3.12.5.5 Tungsten Electrodes

Two percent thoriated tungsten electrodes are recommended for GTAW-DC welding. GTAW-AC welding can be accomplished with either 2% thoriated or zirconium tungsten. For general-purpose use, a 3/32-inch-diameter electrode is preferred. If a stable, molten ball cannot be maintained on the electrode tip during AC welding

because the current is too low, taper the electrode tip over a 1/2-inch length to 3/4 of its original diameter and reform the ball. For GTAW-DC welding, grind the electrode tip to a smooth, uniform, 20-30^{0} included-angle taper.

3.12.5.6 Filler Material

Only A357 aluminum filler metal should be used for weld correction of A357 sand castings. For general-purpose use, 3/32-inch-diameter filler rod produces the best results.

Prior to each weld pass, cut approximately 1/4 inch from the end of the filler wire to be introduced into the weld puddle. During welding, exercise care to keep the tip of the filler metal rod within the inert gas envelope at all times. This will prevent the formation of oxides on the heated portion of the rod.

If impurities appear in or on top of the weld puddle after the addition of filler metal, the filler rod may be contaminated. Occasionally, laps, folds, inclusions, and other discontinuities are produced in the filler metal rods during manufacturing. If the contaminants are on or near the surface of the wire, pickling the wire in acid solutions used for deoxidizing aluminum prior to welding may eliminate the contamination.

3.12.5.7 Edge Wetting and Laps

Exercise care during welding to ensure that the edges of the weld deposit are fused to the walls of the weld groove and not just cast in against them. Avoid an excessively large weld puddle. Deposit the weld in multiple passes if necessary, to keep the size of each weld pass in a controllable range.

Torch manipulation and through melting of each portion of filler rod added to the puddle will minimize premature sidewall melting and eliminate the occurrence of laps and folds.

3.12.5.8 Interpass Cleaning

In multiple-pass welding, it may be necessary to clean the surface of the weld deposit between passes to improve visibility. Although not usually required when welding in the AC mode, interpass cleaning is particularly necessary when welding in the DC mode with helium shielding gas. Although the soot-like "smut" that occurs on the surface of the weld bead and adjacent weld metal is not detrimental to weld quality, it obscures the weld area and particularly the edges of the deposit.

For interpass cleaning, use a hand held wire brush having 0.010-0.013-inch-diameter AISI 300 series stainless steel bristles. Use only light pressure when brushing the completed weld to prevent smearing the metal surface and interfering with subsequent penetrant inspection.

3.12.5.9 Tailouts

Tailout areas are frequent sources of defects in aluminum welds. The rapid solidification rate of aluminum requires that the size of the puddle be minimized when the arc is extinguished to minimize shrinkage pipes and prevent crater cracks.

Frequently, defective or maladjusted foot controls prevent the welder from reducing the welding current to a sufficiently low level to prevent craters. If such a condition exists, refer the problem to qualified welding equipment maintenance personnel for correction.

With many GTAW power sources, the current waveform becomes very distorted at low current levels, increasing puddle rectification and arc reignition problems and producing a very erratic arc. The solid state, square wave, variable polarity duty cycle equipment discussed in Section 3.12.5.2 provides good arc stability and minimizes tailout problems.

As a general multipass welding technique, carefully remelt the tailout area of the previous pass before adding more filler metal and tailing out the current pass. For the final pass, add excessive

filler metal after the metal deposit is completed to build up a beehive-shaped cone well above the top surface of the weld reinforcement. Reduce the current to minimize the puddle size while holding the torch stationary above the top of the cone. Surface contaminants that may have floated along on the puddle will usually become entrapped in the cone and can be removed. Also, if the welding arc becomes extinguished prematurely, the resultant weld crater and/or cracks should be restricted to the area of the cone. The cone, along with any tailout weld imperfections, will be removed during a subsequent bead shaving operation.

3.12.6 Weld Bead Reinforcement Removal

3.12.6.1 Weld Bead Shaving

The engineering drawing or other controlling documentation may require the removal of weld bead face and/or root reinforcement after weld correction. The most efficient means of weld reinforcement removal is by bead shaving. Other methods can be used, but care must be exercised to prevent metal smearing that will interfere with subsequent penetrant inspection operations.

3.12.6.2 Bead Shaving Equipment

Bead shaving can be accomplished satisfactorily using hand-held, air-driven equipment. Suitable bead shaving equipment may be purchased commercially from manufacturers such as Zephyr Manufacturing Co., Inglewood, Calif. or can be built by the user.

3.12.6.3 Bead Shaving Techniques

It is mandatory that the bead shaver cutters be sharp to prevent metal smearing. Use light, smooth strokes to produce a uniform surface. To prevent the adherence of aluminum to the face of the cutter teeth, carefully pass a bar of clean paraffin lightly across the cutter prior to shaving.

In confined areas that do not have sufficient access for a bead

shaver, a sharp, fine-toothed rotary file can be used for weld bead reinforcement removal. A climb cut with a firmly held tool and light, smooth strokes will produce the best results. Paraffin can also be used to minimize aluminum pickup with this technique.

3.12.7 Weld Correction Procedures

3.12.7.1 Weld Correction of Surface Imperfections

Use the following sequence of operations for correcting typical surface imperfections on A357 aluminum sand castings:

1. Determine the location and extent of the imperfections.
2. Determine the type of metal removal equipment and cutters to be used.
3. Remove the surface imperfections to sound base metal using the equipment and techniques described in Section 3.12.3
4. If necessary, solvent clean the weld area as described in Section 3.12.4.
5. Weld the prepared area using the equipment and techniques described in Section 3.12.5. Add 357 filler rod as required to fill the weld cavity and build-up the weld reinforcement at least 1/16 inch above the surface. Tailout carefully on a cone-shaped build-up.
6. Remove the weld bead reinforcement as required to meet the engineering drawing or weld correction instructions using the equipment and techniques described in Section 3.12.6.
7. Submit casting for nondestructive inspection.
8. As required, correct by welding any rejectable imperfections occurring in the corrected area. Process such weld imperfections in the same manner as casting imperfections.

3.12.7.2 Weld Correction of Internal Imperfections

Use the following sequence of operations for correcting typical

internal imperfections in A357 aluminum sand castings:

1. Determine the location and extent of the imperfections.
2. Exercise particular care when locating imperfection detected by radiography. Make sure that the X-ray film and casting bear the same X-ray reference number and that the view markers are identical.
3. Inspect the X-ray film in a viewer to verify the location and extent of the imperfections marked on the X-ray film.
4. Carefully transfer the location of the imperfection from the film to the part, using dividers or other suitable means to ensure accuracy. Mark the area to be corrected with a red marking pencil, General No. 1818, or equivalent. Do not use a common graphite (lead) pencil, felt-tipped pen, or layout fluid because these materials leave a residue which may contaminate the weld.
5. Prepare a weld cavity just large enough to remove the imperfection using the equipment and techniques described in Section 3.12.3.
6. If necessary, solvent clean the weld area as described in Section 3.12.4.
7. Weld the prepared area using the equipment and techniques described in Section 3.12.5. Add A357 filler rod during welding to fill the weld cavity and build-up the weld reinforcement at least 1/16 inch above the casting surface. Tailout carefully on a cone-shaped build-up.
8. If the imperfection extended into the lower half of the original casting thickness, repeat steps 4 through 7 on the reverse side of the part. Make sure that the second side cavity extends into sound weld metal.
9. Remove the weld bead reinforcement as required to meet the engineering drawing requirements or weld correction instructions, using the equipment and techniques described in Section 3.12.6.
10. Submit the casting for nondestructive inspection.

11. As required correct by welding any rejectable imperfections occurring in the corrected area. Process such weld imperfections in the same manner as casting imperfections.

3.12.7.3 Weld Correction of Misruns

Use the following sequence of operations for correcting typical misruns in A357 aluminum sand castings:

1. Closely examine the misrun area for surface contamination, sand entrapment, laps and folds, etc., and rework as required. If the edges of the misrun area are smooth, preweld preparation is usually not required.

2. If necessary, solvent clean the weld area as described in Section 3.12.4.

3. Prior to welding, clamp a 1/4-inch-thick copper backup plate underneath the misrun area. Although not required, the copper plate should be chrome plated to minimize the change of copper pickup in the weld and improve the durability of the copper plate. The copper plate must be clean and free of contaminants that could produce imperfections in the weld.

4. Weld the misrun area using the equipment and techniques described in Section 3.12.5. Since misruns more commonly occur in material thicknesses of 1/2 inch and less, GTAW-AC is the preferred welding mode. Add A357 filler rod during welding to fill the misrun area. Weld around the periphery of the misrun, exercising care to ensure good fusion with the base metal at the edges of the weld deposit. Fill the misrun area in a uniform thickness layer from the outside toward the center in a continuous pass, casting the weld metal against the copper backup plate. Add sufficient filler rod to buildup the weld reinforcement at least 1/16 inch above the casting surface. Tailout carefully on a cone-shaped buildup.

5. Turn the casting over and closely examine the reverse side of the misrun area. If only shallow surface imperfections are visible in the weld, remelt the surface in those areas, adding

a minimal amount of filler material. If deep crevices, laps, or folds are present, remove them to sound metal using the equipment and techniques described in Section 3.12.3.and fill with weld metal.

6. Remove the weld bead reinforcement as required to meet the engineering drawing requirements or weld correction instructions, using the equipment and techniques described in Section 3.12.6.

7. Submit the casting for nondestructive inspection.

8. As required, correct by welding any rejectable imperfections occurring in the corrected area. Process such weld imperfections in the same manner as casting imperfections.

3.12.7.4 Weld Correction of Cracks

Use the following sequence of operations for correcting cracks in A357 aluminum sand castings:

1. Determine the location and extent of the imperfections.

2. Exercise particular care when locating imperfections detected by radiography. Make sure that the X-ray film and casting bear the same X-ray reference number and that the view markers are identical.

3. Inspect the X-ray film in a viewer to verify the location and extent of the imperfections marked on the X-ray film.

4. Carefully transfer the location of the imperfection from the film to the part, using dividers or other suitable means to ensure accuracy. Mark the area to be corrected with a red marking pencil, General No. 1818, or equivalent. Do not use a common graphite (lead) pencil, felt-tipped pen, or layout fluid because these materials leave a residue that may contaminate the weld.

5. Drill a 1/8- to 3/16-inch-diameter "crack stopper" hole at each end of the crack to prevent propogation during welding. The holes should pass through the part, if possible.

6. Prepare a weld cavity just large enough to remove the imperfection using the equipment and techniques described in Section 3.12.3.

7. Weld the prepared area using the equipment and techniques described in Section 3.12.5 exercising particular care to fill the holes. Add A357 filler rod during welding to fill the weld cavity and build up the weld reinforcement at least 1/16 inch above the casting surface. Tailout carefully on a cone-shaped buildup.

8. Turn the part over and repeat steps 4 through 7 on the reverse side of the part. Make sure that the second side cavity extends into sound weld metal.

9. Remove the weld bead reinforcement as required to meet the engineering drawing requirements or weld correction instructions, using the equipment and techniques described in Section 3.12.6.

10. Submit the casting for nondestructive inspection.

11. As required, correct by welding any rejectable imperfections occurring in the corrected area. Process such weld imperfections in the same manner as casting imperfections.

3.13 Heat Treatment/Straightening

3.13.1 Solution Heat Treatment

- o Place casting in heat treat fixture HTF162-00017 for vertical quenching (optional). If castings are not heat treated in fixture, they must be quenched vertically, in upside down position, with slanted beam entering the quench media first.
- o Solution heat treat per A-XXXX, Table IV: 1010 $\pm$ 10°F for 24 hours. Begin soak time when the furnace temperature has recovered to a temperature of 1000 $\pm$ 10°F.
- o Quench parts per A-XXXX,Table IV: maximum quench delay: 8 seconds and water temperature 160 $\pm$ 10°F.
- o Leave part in quench media a minimum of 5 minutes.
- o If part is to be straightened, cover with dry ice for approximately 30 minutes and straighten per section 3.14.2.

3.13.2 Straightening and Natural Age

- Straighten as required to the dimensions shown on drawing 162-00017. Maximum straightening time at 70 $\pm$ 10^{o}F is approximately 6 hours.

- *After straightening, natural* age per A-XXXX Table IV.

  Begin counting time at room temperature 3 hours after removing dry ice or if dry ice is not used begin time immediately after quenching.

3.13.3 Artificial Age

- Artificial age per A-XXXX Table IV.

3.13.4 Inspection of Heat Treated Casting

- Penetrant inspect per section 3.11.4.

3.14 Mechanical Property Testing

- Remove integral test specimens from locations shown on casting drawing 162-00017.

- Fabricate mechanical test specimens per ASTM E-8.

3.15 Machine Casting

- Machine Casting per 162-00018 as required.

3.16 Inspection

3.16.1 Dimensional

- Dimensionally inspect casting per applicable drawing and record results.

3.16.2 Penetrant

- Penetrant inspect machined casting as outlined in Section 3.11.4.

APPENDIX B

DEVELOPMENTAL TOOL ORDER

YC-14 STATION 170 BODY BULKHEAD

TRANSITION STRUCTURE

66

162-00001-1

PAGE 1 OF 23 / 18

START SCHEDULE	COMPLETE SCHEDULE	SCHED ID	PRODUCTION CUSTOMER NO	ASC	PART NUMBER
834	888		STRUCT LAB		162-00001-1

PART NAME: TRANSITION SECT CAST TEST

EWA: 410000

ENGINEERING RELEASE: 008960

MATERIAL SPECIFICATION: SEE ASSY PAGES A1 THRU A16

REL SPLIT 3	F C	C C	WORK ORDER	SUB NUMBER	MFG PLAN NO	SUPP NUMBER	SERIAL NUMBER	INCR	QUANTITY	FOR MATERIAL USE
1M		5	36317	0001			410000		1	
			BUDGET B34108			1000 ~~1200~~ HRS				

SEE A1

DWG ZONE SHT	SECTION	MODEL/S
1		TEST

APPROVED: KAESTNER 5-4598 MORTIMER

FLIGHT ARTICLE: ☐ YES ☒ NO

MATERIAL CODE	FOR PCR USE	REL DATE	ORD BY	O-D DATE	TOTAL QUANTITY	END ROUTING
					1	976

MFG PLAN DATE: 2-6-78

TOOL: 178-0060

CAST-TEST

	TOOL	OPER SEQ NO	PART NUMBER	LABOR STD SETUP	RUN	
			LIAISON : DEAN KAESTNER 655-4598		34	
5100		010	RECORD AND EXPEDITE --- ISSUE DETAILS			
			162 - 00018-1 198 LBS			
6690		020	IDENTIFY COMPONENTS PER ASSEMBLY PAGES			ID
3340		030	ASSEMBLE 64-23110-11 THRU-18 & (2)-59 ATTACH FTGS			
			TO 64-23110-1 STRONG BACK ASSY PER DWG			
			64-23109 SHT 2 AND WELD IN PLACE			
			SEE PARTS LIST A1 & A2			
		040	LOCATE 64-23110-29 THRU-36 PLATES TO 64-23110-1			
			STRONGBACK PER DWG 64-23109 SHT2 AND WELD IN PLACE			
		050	ERECT 64-23109 ASSY. INSTALL SHOP AID BRACES			
			AS REQUIRED TO HOLD ASSY IN POSITION FOR ASSEMBLY.			

STATION 230 & 254.25 PLANS

FURNISHED

198

67

LOC	QTY RECD	DATE RECD	RECD BY	CHECKED BY	POSTED	CUSTOMER INSP	BOEING INSPECTION	TOOL RECD BY	TOOL INSPECTION

[illegible] -00001-1

PAGE 2 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	[illegible]	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
[illegible]			060	ATTACH 162-00002-900 DECK ASSY TO 64-23109					
				STRONGBACK ASSY. PROVIDE SHOP AID AS REQUIRED					
				TO SUPPORT FOR ASSEMBLY PURPOSES.					
				SEE ASSY PARTS LIST A3 & A4					
			070	DRILL (130) .250/.254 DIA. HOLES FULL SIZE					
				COMMON TO 162-00002-2 SKIN AND 64-23110-33					
				ATTACH PLATE PER DWG 64-23109 SHT 2 ZONE					
				C7 VIEW B8. 8-15-7[illegible]					
				.157/.190 Hi-Lok Holes in 162-00002-52 & 162-00005-2 Skin 90 Places OK					
			080	DRILL (8) .250/.254 DIA. HOLES FULL SIZE					
				COMMON TO 64-23110-59 (2) ATTACH FTGS					
				FROM PILOTS IN 64-23110-52 SPLICE PLATES					
				PER DWG 64-23109 SHT 2 ZONE C11 VIEW C10.					
[illegible]			085	INSPECT Holes AS Required			D		
[illegible]			090	DEBURR HOLES AND INSTALL BOLTS ATTACHING					
				162-00002-900 DECK ASSY TO 64-23109					
				STRONG BACK ASSY.					

PART NUMBER 162-00001-1 | PAGE 3 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

FAC WKS	INSPECTION STAMP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
	B 3412			100	OBTAIN 162-00006-900 PRESSURE WEB					
					AND BEAM ASSY. LOCATE 162-00012-900					
					AND 162-00012-901 SIDE PANEL ASSYS					
					PER DWG. CLAMP AND DRILL ALL COMMON					
					LOCATIONS FULL SIZE.					
					SEE ASSY PARTS LIST A4 & A5					
				110	INSTALL FILLERS AS REQ'D AND DRILL ALL					
					HOLES THRU FULL SIZE.					
200										
	B 1690			120	INSPECT HOLE SIZE AS REQUIRED			D		
	B 3408			130	INSTALL FASTENERS DRILLED OPER #100 & #110					
				140	LOCATE 162-00006- AND 162-00012 ASSY TO					
					64-23109- BULKHEAD CLAMP AND DRILL					
					.250/.254 DIA. ATTACH LOCS. COMMON TO					
					SPLICE PLATES AND PRESSURE WEB. DRILL					
					.188/.191 DIA. HOLES COMMON TO SIDEWALLS					
					PER DWG 64-23109 SHT 2.					
					SUPPORT END AS REQUIRED FOR ASSEMBLY					
					SEE ASSY PARTS LIST A5 - A6					

ART NUMBER 162-00001-1 | PAGE 4 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
	B 3410			150	LOCATE AND INSTALL DUMMY 162-00018 BULKHEAD					
					TO 162-00006 PRESSURE DECK AND 162-00012					
					ASSY. INSTALL WITH UNDERSIZE TEMPORARY					
					FASTENERS.					
				160	LOCATE 162-00006-15(4), -16(4) -18(2), -19(2),					
					-2(8), -31(1), BACF3T01E72-25(2), BACF3T04M21-23(2)					
					AND BACF3T02E7-38(8) PER DWG 162-00006					
201					SHT 5 : CLAMP AND DRILL ALL LOCS FULL SIZE					
					EXCEPT COMMON TO 162-00018 BULKHEAD TO					
					BE UNDERSIZE TEMPORARY FASTENERS					
	B 6610			170	INSPECT HOLE SIZE AS REQD.	MAY 4 197?		D		
	B 3410			180	INSTALL FASTENERS DRILLED OPER. # 160					
				190	AT STA. 170 LOCATE 162-00004-900LH AND -901RH					
					WITH FILLERS TO 162-00002 UPPER DECK ASSY AND					
					162-00018 DUMMY BULKHEAD. DRILL ATTACH LOCS					
					FULL SIZE EXCEPT ALL LOCS COMMON TO DUMMY					
					BULKHEAD TO BE UNDERSIZE TEMPORARY FASTENERS.					

NUMBER
62-00001-1

PAGE 5 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
5690			200	INSPECT HOLE SIZES AS REQD.			D	MAY 1978	
3110			210	INSTALL FASTENERS IN LOCS DRILLED OPER # 190					
			220	AT STA. 180 LOCATE 162-00003-911 LH AND -921 RH					
				FRAMES TO 162-00002 UPPER DECK AND 162-00006					
				PRESSURE DECK WITH FILLERS AND 162-000 3-13 (-14 OPP)					
				TO SIDE PANELS, CLAMP AND DRILL ALL					
				FASTENER LOCS FULL SIZE					
			230	LOCATE 162-00013 DETAILS PER DWG, CLAMP					
				AND DRILL ALL FASTENER LOCS FULL SIZE					
				EXCEPT ALL LOCS COMMON TO DUMMY BULKHEAD					
				TO BE UNDER SIZE TEMPORARY FASTENERS.					
			240	AT STA 190 LOCATE 162-00003-912 LH AND -922 RH					
				FRAMES TO 162-00002 UPPER DECK AND					
				162-00006 PRESSURE DECK WITH FILLERS AND					
				162-00003-29, -30 OPP TO 162-00012 SIDE					
				PANELS CLAMP AND DRILL ALL FASTENER LOCS.					
				FULL SIZE.					

PART NUMBER 162-00001-1

PAGE 6

THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

			TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
	3 3410 8			250	AT STA 200 : LOCATE 162-00003-913 LH & -923 RH FRAMES TO 162-00002 UPPER DECK AND 162-00006 PRESSURE DECK ··· LOCATE 162-00003-45 & -46 WITH FILLERS TO 162-00006 PRESS DECK AND 162-00012 SIDE PANELS CLAMP & DRILL PER DWG.					
				260	AT STA 210: LOCATE 162-00003-914 & -924 FRAMES TO 162-00002 UPPER DECK AND 162-00006 PRESS. DECK --- LOCATE 162-00003-61 & -62 WITH FILLERS TO PRESS DECK & 162-00012 SIDE PANELS. CLAMP & DRILL PER DWG.					
				270	AT STA 220: LOCATE 162-00003-915 & -925 FRAMES TO 162-00002 UPPER DECK AND 162-00006 PRESS. DECK --- LOCATE 162-00003-77 & -78 WITH FILLERS TO PRESS DECK & 162-00012 SIDE PANELS. CLAMP & DRILL PER DWG.					

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PART NUMBER: 162-00001-1 | PAGE: 7 | THIS PAGE DATED:

		TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
B 1640			280	INSPECT HOLE SIZES AS REQ'D PER DWG			D		
				FOR STATION 180 THRU STATION 220					
B 3410			290	INSTALL FASTENERS PER DWG @ STATION					
				180 THRU STATION 220					
			300	LOCATE 162-00002 (-43, -44), (-45, -46), (-47, -48)					
				(-49, -50) & (2) -58 DOUBLERS TO					
				162-00002-900 ASSY SEE SHT 3					
				DRILL PER DWG.					
B 2040			310	INSPECT HOLE SIZES AS REQ'D PER DWG			D		
B 3110			320	INSTALL FASTENERS PER DWG					
			330	COMPLETE 162-00002-1 DECK INST'L					
				PER DWG SHT 1 THRU SHT 4 EXCEPT					
				OMIT INST'L OF -4 DOOR ASSY.					
		SEE:		NOTE 6. & NOTE 7. FOR FASTENER INFO.					
		SEE		ASSY PARTS LIST A3-A4					

PART NUMBER 162-00001-1 | PAGE 8 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

	INSPECTION SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY. ACCEPT
	B 3640		✓	340	INSPECT 162-00002-1 DECK INST'L			D		
					COMPLETE PER DWG SHT 1 THRU SHT 4					
					EXCEPT OMIT -4 DOOR INSTALLATION					
					AND SEALING WITH WILL BE					
					ACCOMPLISHED LATER ON THIS ORDER.					
	B 3410			350	COMPLETE: 162-00003-1 FRAME INST'L	STA. 180				
					162-00003-2 FRAME INST'L	STA 190				
	205				162-00003-3 FRAME INST'L	STA 200				
					162-00003-4 FRAME INST'L	STA 210				
					162-00003-5 FRAME INST'L	STA 220				
					PER DWGS SHT 1 THRU SHT 6					
	B 3640			360	INSPECT FRAME INST'L COMPLETE PER					
					DWG SHT 1 THRU SHT 6					
			✓		FRAME 162-00003-1 @ STA 180			D		
					162-00003-2 @ STA 190			D		
					162-00003-3 @ STA 200			D		
					162-00003-4 @ STA 210			D		
					162-00003-5 @ STA 220			D		
			SEE		ASSY PARTS LIST A6 THRU A8					

162-00001-1 | PAGE 9 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

		TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
3410			370	LOCATE 162-00005-900 TO DUMMY BULKHEAD AND TO 162-00002 TOP DECK DRILL ALL HOLES FULL SIZE EXCEPT USE UNDER SIZE TEMPORARY FASTENERS COMMON TO CAST BULKHEAD (OVER)					
3640			380	INSPECT HOLE SIZES COMPLETE PER DWG. EXCEPT THOSE C/T CAST BULKHEAD.			D		
3410			390	INSTALL FASTENERS EXCEPT USE TEMPORARY C/T CAST BULKHEAD					
			400	COMPLETE 162-00004-1 FRAME INST'L PER DWG SHT 1 EXCEPT THOSE HOLES C/T THE DUMMY CAST BULKHEAD					
3640			410	INSPECT 162-00004-1 FRAME INST'L EXCEPT FOR TEMPORARY FASTENERS C/T CAST BULKHEAD			D		
		SEE ASSY PARTS LIST A9							

[illegible] NUMBER	PAGE	THIS PAGE DATED
162-00001-1	10	

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	[illegible]	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
3410	5		420	COMPLETE 162-00005-1 BULKHEAD INST'L					
				Per SHT 1 THRU SHT 4					
			SEE:	NOTE 8.					
				OMIT 20 SEE LATER ON THIS ORDER.					
3690			430	INSPECT 162-00005-1 INST'L EXCEPT			D		
				OMIT SEAL TO BE ACCOMPLISHED					
				LATER ON THIS ORDER					
207			SEE:	ASSY PARTS LIST A9					
3410	5		440	COMPLETE 162-00006-1 WEB INST'L					
				PER DWG SHT 1 THRU SHT 5					
			SEE--	NOTE 32. FOR OPTIONAL FASTENERS.					
			NOTE:	USE UNDERSIZE TEMPORARY FASTENERS					
				C/T DUMMY CAST BULKHEAD					
3690			450	INSPECT 162-00006-1 WEB INST'L			D		
				Complete Per DWG -- EXCEPT FOR					
				UNDERSIZE FASTENERS C/T CAST BLKHD.					
			SEE	ASSY PART LIST A4-A5					

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PART NUMBER	PAGE	THIS PAGE DATED
162-00001-1	11	

[illegible]	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY. ACCEPT
B 3410	$		460	COMPLETE: 162-00007-1 BEAM INST'L					
				162-00008-1 " "					
				162-00009-1 " "					
				162-00010-1 " "					
				162-00011-1 " "					
				Per DWG SHT 1. RESPECTIVELY					
B 3510		✓	470	INSPECT THE FOLLOWING COMPLETE:					
206				162-00007-1 BEAM INST'L STA 180			D		
				162-00008-1 " " STA 190			D		
				162-00009-1 " " STA 200			D		
				162-00010-1 " " STA 210			D		
				162-00011-1 " " STA 220			D		
	SEE:			ASSY PART LIST A10					
B 3410	$		480	COMPLETE 162-00012-1 AND -2 (OPP.)					
				SIDE WALL INST'L Per SHT 1, 2 & 4					
				EXCEPT USE: UNDERSIZE TEMPORARY					
				FASTENERS C/T DUMMY BULKHEAD					
				OVER					

PART NUMBER 162-00001-1 | PAGE 12 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PRODUCTION SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
6640			490	INSPECT 162-00012-1 SIDE WALL INSTL			D		
				EXCEPT: UNDER SIZE FASTENERS S/D CAST					
				BULKHEAD					
B 6640			500	INSPECT 162-00012-2 SIDE WALL INSTL			D		
				EXCEPT: UNDER SIZE FASTENERS S/D CAST					
				BULKHEAD					
		SEE:		ASSY PART LIST A5-A6					
3410	$		510	REMOVE DUMMY CAST BULKHEAD					
209									
			520	INSTALL 162-00018-1 PRODUCTION					
				CAST BULKHEAD					
				LOCATION OK					
			530	LOCATE, DRILL & REAM ALL HOLES					
				C/T 162-00004 & CAST BLK HD Ref XFR 18					
				INSTALL BACB30NE FASTENER.					
				~~SUBSTITUTE FOR BACB30NF~~					
			540	LOCATE, DRILL & REAM ALL HOLES					
				C/T 162-00005 & CAST BLKHD 126 & 127					

20408 ORIG. 11/72

PART NUMBER 162-00001-1 | PAGE 13 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

		TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
3410			550	LOCATE DRILL & REAM ALL HOLES C/T					
				162-00006 & CAST BULKHD ~~Ref XC7~~					
				Ref 33 & 34					
3340			560	INSPECT INSTALLATION of 162-00018-1			D		
				CAST BULKHEAD & FASTENER HOLE					
				SIZES Per DWG. WT 198 lbs					
3410			570	INSTALL BACB30NE Bolts ~~XC7~~ ~~XFR~~ ~~XTD~~					
		AK 8/1/78		FASTENERS Per DWG.					
				SUB. BACB30NE FOR BACB30NF.					
3440			580	INSPECT FASTENER INST'L C/O 162-00018-1			D		
		INSPECTION NOTE:		BACB30NE FASTENERS SUBSTITUTED for BACB30NF					
3410			590	COMPLETE INSTALLATION OF 162-00013-1					
				& -2 BEAM Per DWG.					
		NOTE:		USE [illegible] 40 FASTENERS C/T 162-00018-1					
		SEE:		Assy PARTS LIST A10 - A12					
3440			600	INSPECT 162-00013-1 BEAM INST'L			D		
				INSPECT 162-00013-2 Beam INST'L			D		

[illegible] NUMBER: [illegible]2-00001-1 | PAGE: 14 | THIS PAGE DATED:

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	[illegible]	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP. DATE	QTY. ACCEPT
3410	S		610	FIT AND TRIM THE FOLLOWING DETAILS					
				NOTE: REF. PLANNING SKETCHS PAGES					
				2 THRU 4.					
				LAYOUT AND TRIM TO NET SIZE:					
				162-00014-67 (-68 OPP.) DOUBLER (INTERNAL)					
				162-00014-69 (-70 OPP.) DOUBLER (INTERNAL					
				162-00014-105 SKIN STRAP (INTERNAL)					
211				162-00014-15 (-16 OPP.) SKIN					
				162-00014-19 (-20 OPP) SKIN					
				162-00014-21 (-22 OPP) SKIN					
				162-00014-101 (-102) DOUBLER (EXTERNAL)					
				162-00014-103 (-104) DOUBLER (EXTERNAL)					
				162-00014-91 (-92 OPP) TRIPLER (INTERNAL ~~EXTERNAL~~) UK 820-8					
				162-00014-25 (-27 OPP) SKIN STRAP					
		SEE:		ASSY PARTS LIST A12-A13					
3410			620	INSPECT FITUP AND TRIM OF DETAILS			D		
				LISTED AT OPER 610 PER DWG. SEE OPER.		75			
				[illegible] 2 THRU 4 FOR REWORK					

PART NUMBER 162-00001-1 | PAGE 15 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PRODUCTION SHOP SCHEDULE	ACTION WORK CODE	TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
3 5410	8		630	LOCATE, DRILL & REAM ALL FASTENER LOCATIONS C/T SKIN, DOUBLERS & FRAME STRUCTURE Per 162-00014 SHT 3					
				187/190 DIA HOLES C/T -103/-104 STA 223 OK					
3 6640			640	INSPECT HOLE SIZES AS REQ'D Per DWG & SHOWN ON 162-00014 SHT 3			D		
3 5410	8		650	LOCATE DRILL & REAM ALL FASTENER LOCATIONS C/T SKIN, DOUBLERS & FRAME STRUCTURE Per 162-00014 SHT 4					
			NOTE:	NO FASTENERS AT SKIN SPLICE WITHIN 2.10 DIM @ STA 230.					
			NOTE	ALL FASTENER THRU CAST BLKHD TO BE XC7L HI LOK.					
3 6640			660	INSPECT HOLE SIZES AS REQ'D Per DWG & AS SHOWN ON 162-00014 SHT 4			D		

BT 142 MAY 15 1978

PART NUMBER 162-00201-1 | PAGE 16 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

JC NO.	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY ACCEPT
	B 3410B			670	LOCATE, DRILL & REAM ALL FASTENER					
					LOCATIONS C/T SKIN, DOUBLERS & FRAMES					
					Per 162-00014 SHT 5 NOTE 18					
					LOCATE & HOLE SAW 3.00 DIA HOLE					
					THRU Ref STA 185 & WL 108					
	B 6690			680	INSpect HOLE SIZE @ oper 670 AS REQ'D			D		
					Per DWG 162-00014 - SHT 5					
	B 3410			690	DE BURR DOUBLERS & SKINS AS REQ'D		DWC 8-20-[illegible]	[illegible]		
					AND APPLY FAYING SURFACE SEAL					
					Per BMS 5-95 AND 11 SEE PLANNING NOTE BACK SIDE.					
				700	INSTALL ALL FASTENER AS INDICATED					
					ON 162-00014 SHT 1 thru 5 AND Per					
					10					
	B 6690			710	INSpect FASTENER INST'L Per 162-00014-1			D		
					AND Per 10					

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PART NUMBER: 162-00001-1 | PAGE: 17 | THIS PAGE DATED:

		TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY ACCEPT
3910	5		720	LOCATE AND DRILL .250 .250 HOLE C/T SKIN					
				& 64-23110-2 STRONG BACK See	OPER 070				
				SEE VIEW B-8 PAGE	2 of PLAN				
				LOCATE & DRILL .188 .191 HOLES C/T SIDE					
				WALL AND 64-23110-2 STRONG BACK See	OPER 070				
				SEE VIEW A-7	PAGE 2 of PLAN				
3640			730	INSPECT HOLES AS REQ'D FOR OPER	8/29/8		B		
				720 (JOIN TRANSITION TO STRONG BACK)	See OPER 085				
				DWG 64-23109 SHT 2	PAGE 2 OF PLAN				
				DUPLICATE OPER SEE					
				[illegible]					
3910	5		740	INSTALL, BAC B30NE FASTENERS TO					
				COMPLETE JOIN OF TRANSITION SECTION					
				TO STRONG BACK					
				SEE 64-23109 DWG. See	OPER 070				
					PAGE 2 OF PLAN				
					8/29/8				
3640			750	INSPECT OPER 740 PER 64-23109 See	OPER 085		B		
		NOTE:		THIS SHOULD COMPLETE 162-00001-1 EXCEPT					
				SEALING AND INSTALLATION OF 162-00002-4	DOOR ASSY.				

NUMBER 162-00001-1

PAGE 18 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	[illegible]	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
			755	SEE PAGES 19 THRU 23 FOR SPLICE ADDITION					
3410			760	SEAL 162-00001-1 ASSY FOR 7 PSI					
				INTERNAL PRESSURE PER ENG'R					
				INSTRUCTION					
			770	INSTALL 162-00002-4 DOOR ASSY					
				PER DWG. OMIT INST'L UNTIL PRESSURE					
				TEST AT D.C. NWC 8-29-78					
		SEE :		ASSY PARTS LIST A14					
3510			780	INSPECT 162-00001-1 INST'L Complete			D		
				Per DWG.					
		NOTE :		PRESSURE TEST & FUNCTIONAL					
				TEST TO BE ACCOMPLISHED ON					
				SEPARATE ORDER					
5200			790	CLEAR ORDER AND ROUTE 'P' COPY					
				TO: DEAN KAESTNER D.C.					

215

PART NUMBER 162-00001-1 | PAGE 19 | THIS PAGE DATED 4-26-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

REV.	PRODUCTION SHOP & SCHEDULE	WORK	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	SYM	INSP DATE	QTY. ACCEPT
		NOTE:			PAGES 19 THRU COVER THE ADDITION					
					OF THE SKIN AND PRESSURE DECK					
					SPLICE Per REV. "A" ON DWG'S					
					162-00002, 162-00012 & 162-00014					
	5200			755 .01	ISSUE MATERIAL Per P/R 086033 (ATTACHED)					
	5410			755 .02	MAKE THE FOLLOWING ITEMS:					
				755 .03	FABRICATE (1) 162-00002-62 STRAP (.250/.254 HOLES -62)			D		1
					USE: 2024-T3 MAT'L AND TRIM Per PCM					
					RUBBER STAMP P/N MAT'L I.D.					
				755 .04	FABRICATE (1) 162-00002-64 STRAP			D		3
					USE: 7075-T6 MAT'L AND TRIM Per PCM					
					RUBBER STAMP P/N S. Codec... MAT I.D. 7075-T6 QQ-A-250/12					
				755 .05	FABRICATE (1) 162-00002-67 & (1)-68 (OPP -67)			D		
					USE: 7075-0 MAT'L, BRAKE FORM Per PCM					
					HEAT TREAT TO T-6 CONDITION			R		
					RUBBER STAMP RESPECTIVE P/N					

216

PART NUMBER 162-00001-1 | PAGE 20 | THIS PAGE DATED 4-28-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

			TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN		INSP DATE	QTY. ACCEPT
	3110	5		755 .06	FABRICATE (1) 162-00002-71 & (1) -72 (OPP -71)			D		
					USE: 7075-0 MAT'L, BRAKE FORM PER FCM					
					HEAT TREAT TO T-6 CONDITION			R		
					RUBBER STAMP RESPECTIVE P/N					
					-72					
					-71					
				755 .07	SAW CUT 162-00002-3 WEB @ STA. 175			D		
					PER [17] --- Remove Sharp edges.					
					RE-PART NO. FWD SECTION AS 162-00002-63					
217										
				755 .08	SAW CUT 162-00002-25 & -26 ANGLES			D		
					@ STA. 185.60 PER [17]					
					Remove Sharp edges					
					RE-PART NO FWD. SECTION AS 162-00002-66					
					AND 162-00002-69 Respectively					
				755 .09	SAW CUT 162-00002-15 STRAP Shim @ STA 175.0			D		
					~~AND @ STA. 170.20~~ -- Remove Sharp edges					
					RE-PART NO FWD. SECTION AS 162-00002-65					
					SCALE P/W DWG					

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MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PART NUMBER	PAGE	THIS PAGE DATED
162-00001-1	21	5-1-78

		TOOL	OPER. NO.	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY. ACCEPT
110	5		755 .10	FABRICATE (1) 162-00012-201 &			D		(2)
				(1) 162-00012-202 STRAP. I.D. OK (2)					
				USE: 7075-T6 SHT Per [14]					
				TRIM & CHAMFER Per PCid. Scale B/W Dwg					
				RUBBER STAMP Respective P/N					
			755 .11	FABRICATE (2) 162-00014-107 AND (2)			D		
				162-00014-108 SKIN SPLICES Scale B/W Dwg.					
				USE: 2024-T3 SHEET Per [3]					
				RUBBER STAMP Respective P/N					
			755 .12	FABRICATE (2) 162-00014-110 & (4)			D		
				162-00014-111 TAPERED SHIMS					
				MATERIAL OPTIONAL Scale B/W Dwg.					
				RUBBER STAMP P/N					
			755 .13	FABRICATE (2) 162-00014-116 SKIN SPLICE.					(2)
				MAT'L: 2024-T3 SHT QQ-A-250/5					
				RUBBER STAMP P/N Scale B/W Dwg.					

PART NUMBER	PAGE	THIS PAGE DATED
162-20001-1	22	5-1-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

		TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP. SYM	INSP. DATE	QTY. ACCEPT
3110	$		755 .14	FABRICATE (4) 162-00014-118 SHIMS.			D		
				MATERIAL OPTIONAL Scale B/W Dwg.					
				RUBBER STAMP P/N					
			755 .15	SAW CUT (1) 162-00014-19 SKIN AND			D		
				(1) 162-00014-20 SKIN AT STA. 185.0					
				Remove Sharp EDGES Scale B/W Dwg.					
				RUBBER STAMP Fwd Sect -109					
			775 .16	SAW CUT (1) 162-00014-21 AND (1)		BT 442	D		
				162-00014-22 SKIN AT STA 185.0					
				Remove SHARP EDGES. Scale B/W Dwg.					
				RUBBER STAMP FWD Sect -112 & -113					
				Respectively					

219

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PART NUMBER: 162-00001-1 | PAGE: 23 | THIS PAGE DATED: 5-1-78

	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR SETUP	LABOR RUN	INSP	INSP DATE	QC ACCEPT
3410	S		775 .17	SAW-CUT (1) 162-00014-101 & (1) -102			D		
				DOUBLERS [illegible] SCALE P/W TAPE.					
				Remove Sharp EDGES					
				RUBBER STAMP FWD Sect. -114 & -115					
		[illegible] 5/5/78	[illegible]	Respectively					
				~~SAW CUT [illegible] & [illegible] ON STA. 185~~					
				-69 -70					
			775 .18	ASSEMBLE SPLICE SECTIONS PER DWG'S					
				Rev. "A". See "DWG REV LOG" PAGE A17					
				OF PLAN					
		NOTE:		ALL FASTENERS ALONG FWD SIDE OF					
				SPLICE ARE TO BE REMOVABLE					
3690			775 .19	INSPECT Complete SPLICE INSTALLATION			D		
				Per. Rev 'A' DWG'S					
			775 .20	RETURN TO OPERATION 760 PAGE 18					
				OF PLAN.					

PART NUMBER 162-00001-1 | PAGE A1 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

OPERATIONS & INSTRUCTIONS

ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE	LABOR STD SETUP	LABOR STD RUN
STANDARDS					U/O
BACB30NE3-7	BOLT	116		64-23109-1	
4-7		484			
4-8		8			
4-9		32			
4-10		12			
BACB30NE4-13	BOLT	4			
BACN10JC3	NUT	100			
BACN10JC4	NUT	556			
AN960-10	WASHER	200			
AN960-416	WASHER	1080		64-23109-1	
BACN10JR04	PLATE NUT	22		162-0000-1	
NAS1304-11	BOLT	22		162-0000-1	

221

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64-00001-1 | PAGE A2 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY ACCEPT
		ASSEMBLY, PARTS LIST					
		COMPONENTS OF 64-23709-1 INSTL USED OPER	030 &	040			

PART NO.	NAME	QTY.	STORE
64-23110-1	PRESSURE PLATE ASSY	1	976
-15	ATTACH FTG	1	
-16		1	
-17		2	
-18		1	
-11		1	
-12		1	
-13		1	
-14	ATTACH FTG	1	
-29	PLATE	1	
-30		1	
-31		1	
-32		1	
-33		1	
-34		1	
-35		1	
-36	PLATE	2	
64-23110-59	ATTACH FTG	2	976

162-00001-1 | PAGE A3 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

OPERATIONS & INSTRUCTIONS

ASSEMBLY PARTS LIST

COMPONENTS OF 162-00002-1 TOP DECK INSTL.

INSTALLED AT OPER # 060-090

PART NO.	NAME	QTY.	STORE	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY ACCEP
162-00002-900	DECK ASSY	1	112 FEB 24 1978					
-25	AFT EDGE CAP	1						
-26	OPP-25	1						
-27	FWD EDGE CAP	1						
-28	OPP-27	1						
-29	STRAP	2						
-30	STRAP	2						
-31	FILLER	2	MAR 1978					
-4	DOOR ASSY	1						
-39	STIFFENER	1						
-40	OPP-39	1						
-42	FILLER	2						
-43	CHORD BL35	1						
-44	OPP-43	1						
-45	WEB BL35	1						
-46	OPP-45	1						
-47	CHORD BL28	1						
162-00002-48	OPP-47	1	MAR					

PART NUMBER 162-00001-1 | PAGE A4 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	LABOR STD RUN	INSP	INSP DATE	QTY ACCEPT
					ASSEMBLY PARTS LIST								
					PART NO.	NAME	QTY.	STORE					
	(162-00002-1 CONT)				162-00002-49	WEB BL28	1						
					-50	OPP-49	1						
					-51	END CAP	1						
					-52	FILLER	2						
					-53	SPLICE	2						
					-54	SPLICE	2	6					
					-55	SPLICE	2						
					-56	FILLER	2	MAR 1978 6					
					-57	FILLER	2						
					-58	DOUBLER	2						
					162-00002-59	FILLER	2						
	COMPONENTS OF 162-00006-1 PRESSURE WEB INSTL												
					162-00006-900	PRESS. WEB & BEAM ASSY	1	FEB 1978					
					-2	FILLER	8						
					-8	FILLER	2						
					-15	CHANNEL	4						
					-16	OPP-15	4						
					-18	PLATE	2	MAR 18					
					162-00006-19	PLATE	~~2~~ 1						

PART NUMBER 162-00001-

PAGE A5

THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PROD. SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	LABOR STD RUN	INSP STM	INSP DATE	QTY ACCEP-
				ASSEMBLY PARTS LIST								
				PART NO.	NAME	QTY.	STORE					
(162-00006-1 CONT)				162-00006-31	CLIP	1						
				BACF3T01E72-25	FILLER	2						
				BACF3T04M21-23	FILLER	2						
				BACF3T02E7-38	FILLER	8	MAR 1978 18					
				162-00006-56	PLATE	1						
COMPONENTS OF 162-00012-1 SIDE PANEL INSTL												
225				162-00012-27	STRAP	1						
				162-00012-18	FILLER	1						
				BACF3F7L8	FILLER	1						
				BACF3T02M14-26	FILLER	1						
				BACF3T02E7-14	FILLER	1						
				BACF3T01G6-8	FILLER	2						
				BACF3T01G14-17	FILLER	1						
				162-00012-901	SIDEWALL ASSY	1	MAR 18					

162-00001-1 | PAGE A6 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	RUN	INSP SYM	INSP DATE	QTY ACCEPT
		ASSEMBLY PARTS LIST								
		PART NO.	NAME	QTY.	STORE					
		COMPONENTS OF 162-00012-2 SIDE PANEL INSTL								
		162-00012-27	STRAP	1						
		162-00012-18	FILLER	1						
		BACF3F7L8	FILLER	1	MAR 1978 18					
		BACF3T02M14-26	FILLER	1	MAR 1978 18					
		BACF3T02E7-14	FILLER	1						
		BACF3T01G6-8	FILLER	2	MAR 18					
		BACF3T01G14-17	FILLER	1	1978 18					
		162-00012-902	SIDEWALL ASSY	1	18					
		COMPONENTS OF 162-00003-1 FRAME INSTL								
		162-00003-911	STA.180 FRAME ASSY (LH)	1	FEB 1978 24					
DHC 1-24-78		162-00003-~~912~~ 921	" " " " (RH)	1						
		162-00003-19	FILLER	8						
		BACF3T01D50-10	FILLER	2						
		BACF3T01E7-9	FILLER	2						
		BACF3T01C34-9	FILLER	1						
		BACF3F262 26	FILLER	2	MAR 1978 2					

NUMBER 162-00001-1 | PAGE A-7 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

TOOL | OPERATION SEQUENCE NO. | OPERATIONS & INSTRUCTIONS | LABOR STD SETUP | RUN | INSP SYM | INSP DATE | QTY. ACCEPT

ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE
COMPONENTS OF 162-00003-2 FRAME INSTL			
162-00003-912	STA 180 FRAME ASSY (LH)	1	FEB 24 1978
162-00003-922	" " " (RH)	1	FEB 24 1978
162-00003-19	FILLER	8	
BACF3T01D50-10	FILLER	2	
BACF3T01E7-9	FILLER	2	
BACF3T01C34-9	FILLER	1	
BACF3F26L26	FILLER	2	BT 242
COMPONENTS OF 162-00003-3 FRAME INSTL			
162-00003-913	STA 200 FRAME ASSY (LH)	1	BT FEB 24 1978
-923	" (RH)	1	FEB 24 1978
-19	FILLER	8	
BACF3T01D50-10	FILLER	2	
BACF3T01E7-9	FILLER	2	
BACF3F26L26	FILLER	2	

NUMBER 162-00001-1 | PAGE A8 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

OPERATIONS & INSTRUCTIONS

ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE
COMPONENTS OF 162-00003-4 FRAME INSTL			
162			
162-00003-914	STA 210 FRAME ASSY (LH)	1	BT FEB 24 1978
162-00003-924	" (RH)	1	FEB 24
162-00003-19	FILLER	8	
BACF3T01E7-9	FILLER	2	
BACF3T01B28-9	FILLER	2	
BACF3F26L26	FILLER	2	
COMPONENTS OF 162-00003-5 FRAME INSTL			
162-00003-915	STA 220 FRAME ASSY (LH)	1	BT FEB 24 1978
162-00003-925	" " (RH)	1	FEB 24
162-00003-19	FILLER	8	2
BACF3T01D50-10		2	
BACF3T01E7-9		4	
BACF3T01G7-10		4	
BACF3T02F5-10		2	
BACF3F26L26	FILLER	2	

ART NUMBER 162-00001-1 | PAGE A9 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY ACCEPT
		ASSEMBLY PARTS LIST								
		PART NO.	NAME	QTY.	STORE					
		COMPONENTS OF 162-00004-1 FRAME INSTL.								
		162-00004-900	FRAME ASSY 170 (LH)	1	MAR 1978 30					
		-901	" " " (RH)	1						
		-11	CHORD SPLICE	1						
		-12	OPP-11	1						
		-13	FILLER	2						
		-14	FILLER	2	30					
		162-00004 -15	FILLER	2						
		COMPONENTS OF 162-00005-1 CANTED BLKHD INSTL								
		162-00005-900	BLKHD ASSY	1						
		-3	CHORD	1	MAR 1978					
		-4	OPP-3	1						
		-18	GUSSET	2						
		-23	FILLER	2	MAR 27					
		-29	FILLER	2						
		-51	CLIP	1	MAR 1978					
		162-00005-52	OPP-51	1						
		BACF3T01C18-18	FILLER	2	MAR 1978 27					

229

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NUMBER 162-00001-1 | PAGE A10 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

OPERATIONS & INSTRUCTIONS

ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE
162-00007-900	BEAM ASSY	1	976
162-00008-900	BEAM ASSY	1	976
162-00009-900	BEAM ASSY	1	976
162-00010-900	BEAM ASSY	1	976
162-00011-900	BEAM ASSY	1	976

COMPONENTS OF 162-00013-1 & -2 INST'L

PART NO.	NAME	QTY.	STORE
162-00013-3	CHORD TIE	1	976
-4	OPP-3	1	976
-5	WEB	1	976
-6	OPP-5	1	976
-11	WEB	1	976
-12	OPP-11	1	976
-13	ANGLE	1	976
-14	OPP-13	1	976

230

PLAN NUMBER 162-00001-1 | PAGE A11 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

ASSEMBLY	WORK	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY ACCEPT
				ASSEMBLY PARTS LIST								
				PART NO.	NAME	QTY.	STORE					
				162-00013-15	CLIP	1	976					
				-16	OPP-15	1						
				-17	CLIP	1						
				-18	CLIP	1						
				-19	CLIP	1						
				-20	OPP-19	1						
				-21	WEB	1						
				-22	OPP-21	1						
				-23	WEB	1						
				-24	OPP-23	1						
				-25	ANGLE	1						
				-26	OPP-25	1	976					
				-27	CLIP	1						
				-28	OPP-27	1						
				-29	CLIP	1						
				-30	OPP-29	1						
				-31	CLIP	1						
				-32	OPP-31	1						
				-33	CLIP	2						
				162-00013-34	DOUBLER	2	976					

T NUMBER: 162-00201-1 | PAGE: A12 | THIS PAGE DATED:

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PRODUCTION SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	LABOR STD RUN		INSP DATE	QTY. ACCEPT
				ASSEMBLY PARTS LIST								
				PART NO.	NAME	QTY.	STORE					
				162-00013-35	ANGLE	1	976					
				-36	OPP-35	1						
				-39	ANGLE	1						
				-40	OPP-39	1						
				-41	ANGLE	2						
				-42	ANGLE	2						
				-43	FILLER	2						
232				-44	FILLER	2						
				-45	FILLER	2						
				-49	ANGLE	1						
				-50	ANGLE	1	976					
				BACF3T07N15-24	FILLER	2	976					
				BACF3T03N18-19	FILLER	2	976					
	COMPONENTS			OF 162-00014-1	SKIN INST'L							
				162-00014-15	SKIN	1	976					
				-16	OPP-15	1						
				-19	SKIN	1						
				-20	OPP-19	1	976					

PART NUMBER 162-00001-1 | PAGE 113 | THIS PAGE DATED

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

PROJECT ON SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS				LABOR STD SETUP	LABOR STD RUN	NON SYM	INSP. DATE	QTY ACCEPT
				ASSEMBLY PARTS LIST								
				PART NO.	NAME	QTY.	STORE					
				162-00014-21	SKIN	1	976					
				-22	OPP -21	1						
				-25	STRAP	1						
				-27	OPP -25	1						
				-67	DOUBLER	1						
				-68	OPP -67	1						
				-69	DOUBLER	1						
233				-70	OPP -69	1						
				-91	TRIPLER	1						
				-92	OPP -91	1						
				-101	DOUBLER	1	MCA					
				-102	OPP -101	1						
				-103	DOUBLER	1						
				-104	OPP -103	1	MCA					
				-105	STRAP	1	976					
				BACF3F8A22	FILLER	2	976					

162-00001-1 A14

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

OPERATIONS & INSTRUCTIONS

ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE
COMPONENTS OF 162-00001-1 INST'L			
162-00002-1	TOP DECK INSTL	1	MOA
162-00003-1	FRAME INSTL 180	1	
162-00003-2	" 190	1	
162-00003-3	" 200	1	
162-00003-4	" 210	1	
162-00003-5	" 220	1	
162-00004-1	" 170	1	
162-00005-1	CANTED BLKHD INSTL	1	
162-00006-1	PRESS WEB INSTL	1	
162-00007-1	PRESS BEAM 180	1	
162-00008-1	" " 190	1	
162-00009-1	" " 200	1	
162-00010-1	" " 210	1	
162-00011-1	" " 220	1	
162-00012-1	SIDE PANEL INSTL	1	
162-00012-2	OPP-1	1	
162-00013-1	SLANT BEAM INSTL	1	
162-00013-2	OPP-1	1	
162-00014-1	SKIN PANEL INSTL	1	MOA

162-00001-1 | PAGE A15 | THIS PAGE DATED 4-27-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

OPERATIONS & INSTRUCTIONS

SPLICE ADDITION - ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE
162-00002 -62	STRAP-SPLICE	1	MOA
-63	FWD. WEB	1	MAKE FROM -3
-64	STRAP-SPLICE	2	MOA
-65	SHIM	2	MAKE FROM -15
-66	EDGE CAP	1	MAKE FROM -25
-67	CAP SPLICE	1	MOA
-68	OPP -67	1	MOA
-69	OPP -66	1	MAKE FROM -26
-71	~~DOUBLER~~ CAP ANGLE	1	MOA ~~FROM -69~~
-72	OPP -71	1	MOA ~~FROM -70~~
162-00012 -201	STRAP	1	MOA
-202	STRAP	1	MOA
162-00014 -71	DOUBLER	1	MAKE FROM -69
-72	OPP -71	1	MAKE FROM -70

162-00201-1 | PAGE A16 | THIS PAGE DATED 4-27-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

TOOL	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	RUN	INSP DATE

SPLICE ADDITION - ASSEMBLY PARTS LIST

PART NO.	NAME	QTY.	STORE
162-00014-107	SKIN SPLICE	2	MOA
-108	SKIN SPLICE	2	MOA
-109	SKIN	1	MAKE FROM -19
-110	TAPERED SHIM	2	MOA
-111	" "	4	MOA
-112	SKIN	1	MAKE FROM -21
-113	OPP -112	1	MAKE FROM -22
-114	EXTERN. DOUBLER	1	MAKE FROM -101
-115	OPP -114	1	MAKE FROM -102
-116	SKIN SPLICE	2	MOA
-118	SHIM	4	MOA
BACB30NF3-*	BOLT	AR	*DETERMINE ON ASSY.
BACB30NF4-*	BOLT	AR	*DETERMINE ON ASSY.
BACN10JC3	NUT	AR	
BACN10JC4	NUT	AR	

APPENDIX C

CAST BULKHEAD REMOVAL ORDER

FATIGUE TEST SETUP

YC-L$ STATION 170 BODY BULKHEAD

PART NUMBER	PAGE	PART NUMBER
64-23107-1	1 OF 8	64-23107-1

PART NAME	EWA	ENGINEERING RELEASE	MATERIAL SPECIFICATION
CAST BULKHEAD REMOVAL ORDER	510000	Phase V	FATIGUE TEST SETUP

REL SPLIT 3	P.C.	C.C.	WORK ORDER	SUB NUMBER	MFG PLAN NO	SUPP NUMBER	SERIAL NUMBER	INCR	QUANTITY	FOR MATERIAL USE
2M		5	B6318	0000			510000		1	

STOCK SIZE:

DCN ADCN	DWG ZONE & SHT	SECTION	MODEL/S
			TEST

PLANNER	PHONE	APPROVED	FLIGHT ARTICLE	MFG PLAN DATE
KAESTNER	655-4593	AK.	[ ] YES [X] NO	9-13-78

MATERIAL CODE	FOR PCR USE	REL DATE	ORD BY	ORD DATE	TOTAL QUANTITY	END ROUTING
			AKK	9-15-8	1	PCA976

DEVELOPMENTAL TEST SUPPORT ORDER

REJECT TAGS	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPER SEQ NO	OPP	PART NUMBER	PCR	NOMENCLATURE	STDS/PROC	QTY	FROM DRAWING/LOC	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY ACCPT.

BOEING Manufacturing Engineer: Dean Kaestner B-5100 Mailstop 47-56
(206)245-4598 CCSA

See the drawing revision log attached to the back of this order.

This order defines the sequence to be used for the removal of the Cast Bulkhead (162-00018) from the transition structure (162-00001-1) following completion of the fatigue test.

Engineering Concurrance prior to tear down:

SIGNATURE DATE

STORED IN PCA	BIN LOC.	QTY RECD	DATE RECD	RECD. BY	CHECKED BY	POSTED	CUSTOMER INSP	BOEING INSPECTION	TOOL RECD BY	TOOL INSPECTION

PART NUMBER 64-23107-1 | PAGE 1 | THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	[illegible]	[illegible]	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY. ACCEPT
				010	Disconnect all actuator clevises from the dummy trunnion (64-23112-1).					
					Reference Sketch #1 and Drawing 64-23107.					
				020	Disconnect all instrumentation leads to the dummy trunnion (64-23112-1)					
					the two trunnion struts (64-23112-2) and the cast bulkhead (162-00018).					
					Reference Sketch #1					
				030	Support the dummy trunnion (64-23112-1) NOTE: The dummy trunnion					
					weighs 445 lbs. Remove bolts (8) securing the struts to the trunnion					
					and the strong back. The struts weighs approx. 65 lbs. each.					
				040	Remove the (4) bolts securing the dummy trunnion to the cast bulkhead.					
					Reference: Drawing 64-23107					
					NOTE: Extreme care must be used to support the dummy trunnion.					
				050	Remove the access door (162-00002-5) from the pressure deck of the					
					transition structure.					

PART NUMBER 64-23107-1 | PAGE 2 | THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

			TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
				050 (cont)	Reference Drawing 162-00002, Sheet 4.					
				060	Remove all bolts forward from Station 190 and common to the 162-00012-27 strap and the 162-00012-3 T angle (Typical both sides).					
					See sketch #2 and Drawing 162-00012, Sheet 2.					
				070	Remove all the bolts common to the 162-00014-105 skin strap and the 162-00018 cast bulkhead.					
					See sketch #2, and Drawing 162-00014 24 Sheet 5.					
				080	Remove all the bolts forward from Station 190 and common to the 162-00014-25 splice strap (Typical both sides).					
					See sketch #2 and Drawing 162-00014 24 Sheet 4.					

PART NUMBER 64-23107-1 | PAGE 3 | THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

REJECTIONS	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SET-UP	LABOR STD. RUN	INSP SYM	INSP. DATE	QTY. ACCEPT
				090	Remove all the bolts forward from Station 190 and common to the splice					
					angles 162-00002-27, -66, -67, and -71 (Typical both sides).					
					See sketch #2 and Drawing 162-00002, YY & XX, Sheet 3.					
				100	Remove all the bolts common to the splice strap (162-00014-116 (Typical					
					both sides).					
					See sketch #2 and Drawing 162-00014, Sheet 3.					
				110	Remove all the bolts common to the 162-00014-108 splice.					
					Reference Station 185 (Typical both sides).					
					See Sketch #3 and Drawing 162-00014 24 25 Sheet 5.					
				120	Remove all the bolts common to the 162-00014-107 splice.					
					Reference Station 185 (Typical both sides).					

PART NUMBER 64-23107-1 | PAGE 4 | THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

SEC TIONS	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP. DATE	QTY. ACCEPT
				120	(cont.) See sketch #3 and Drawing 162-00014 24 25 Sheet 3.					
				130	Remove all the bolts common to the 162-00014-114 and 115 skin doublers forward from Station 180.					
					See Sketch #3 and Drawing 162-00014 Sheet 3 and Drawing 162-00002, Sheet 3 24					
				140	Remove all the bolts common to the slant beam support attached at the 162-00018 cast bulkhead and the frame at Station 180.					
					See Sketch #4 and Drawing 162-00013 10 Sheet 1.					
				150	Remove all the bolts common to the cast bulkhead (162-00018) and the canted bulkhead (162-00005).					
					See Sketch #4 and Drawing 162-00005 27 Sheet 4.					

PART NUMBER -23107-1

PAGE 5

THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP. DATE	QTY. ACCEPT
				160	Remove all the bolts common to the cast bulkhead and the canted bulkhead					
					support channels.					
					See sketch #4 and Drawing 162-00005 27 Sheet 3.					
				170	Remove all the bolts common to the frame installation at Station 170					
					(162-00004), the pressure deck (162-00002) and the cast bulkhead					
					(162-00018).					
					See Sketch #4 and Drawing 162-00004 8 Sheet 1					
				180	Remove all the bolts common to the pressure deck splice 162-00002-62					
					and the splice strap (162-00002-64)					
					Reference Drawing 162-00002, Sheet 4, Revision A.					
				190	Remove canted bulkhead installation from cast bulkhead.					
					See Sketch #5					

PART NUMBER 64-23107-1 | PAGE 6 | THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

[illegible]	[illegible]	[illegible]	TOOL	OPERATION SEQUENCE NO.	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP. DATE	QTY. ACCEPT
				200	Remove all the bolts common to the attach angle (162-00006-31) and the					
					cast bulkhead (162-00018).					
					Reference Drawing 162-00006, Sheet 4 34					
				210	Remove all the bolts common to the (8) channels (162-00006-15, -16 opp)					
					and the cast bulkhead (162-00018).					
					Reference Drawing 162-0006 Sheet 5 34					
				220	Remove all the bolts common to the wheel well sice panels (162-00012)					
					and the cast bulkhead (162-00001) Typical both sides.					
					Reference Drawing 162-00012 Sheet 2 29					
				230	Rig the Cast bulkhead for removal. NOTE: The cast bulkhead (162-00018)					
					weighs approximately 198 lbs.					

PART NUMBER 64-23107-1 | PAGE 7 | THIS PAGE DATED 9-13-78

MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

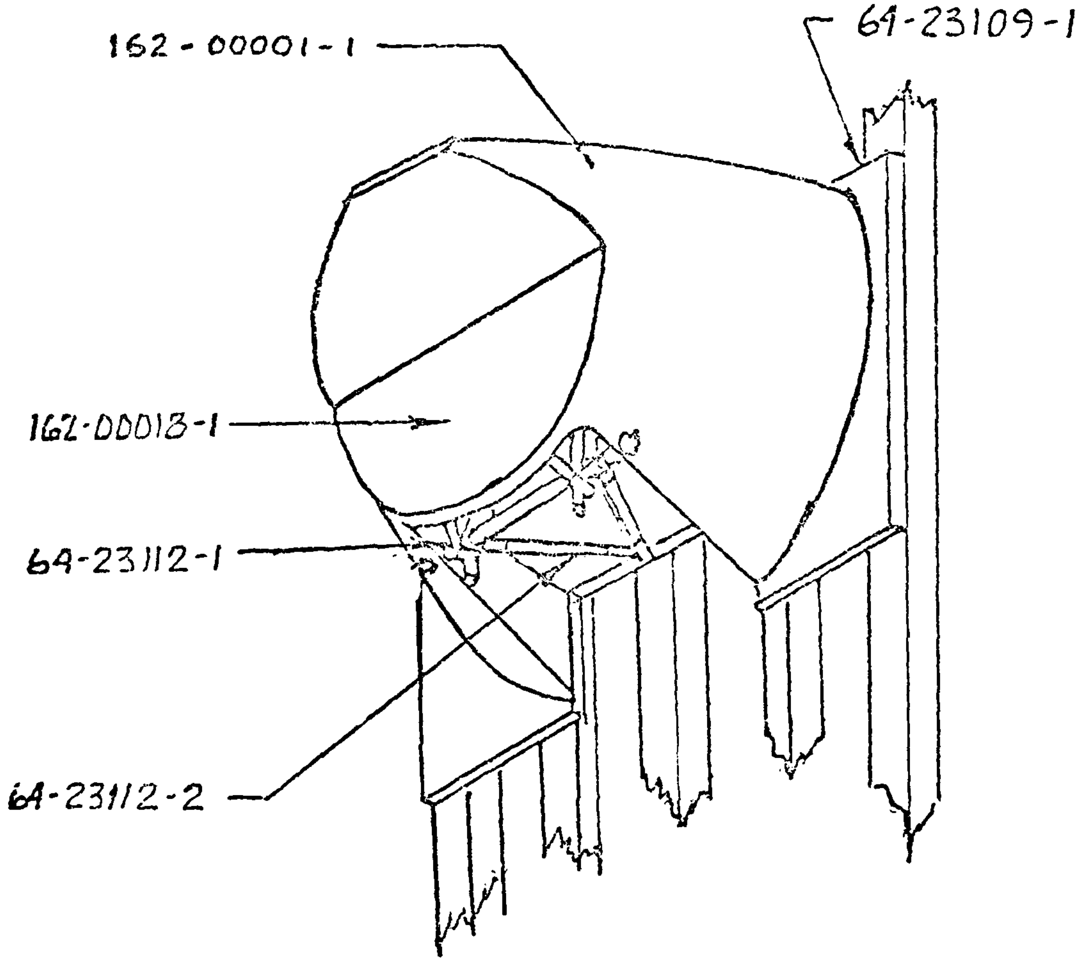
...IONS	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD. SETUP	LABOR STD. RUN	INSP SYM	INSP DATE	QTY. ACCEPT
				240	Remove all the bolts common to the pressure deck web (162-00006) and					
					the cast bulkhead (162-00018).					
					Reference Drawing 162-00006 Sheet 5 33					
				250	The cast bulkhead (162-00018) can now be moved forward for removal					
					from the transition structure. (162-00001-1)					
					REWORK PRIOR TO RE-ASSEMBLY					
				260	Measure and record condition of the bushings (NAS 73-15E015 and			M/R		
					NAS 73-16E101) located in the Dummy Trunnion (64-23112-1).					
					Replace these bushings if required, line ream these bushings to high					
					side of the bushing tolerance.					
				270	Measure and record the inside diameter of the bushings in the #4 cast			M/R		
					Bulkhead.					
					C/D with Engineer for tolerance requirements.					

PART NUMBER 64-23107-1 | **PAGE** 8 | **THIS PAGE DATED** 9-13-78

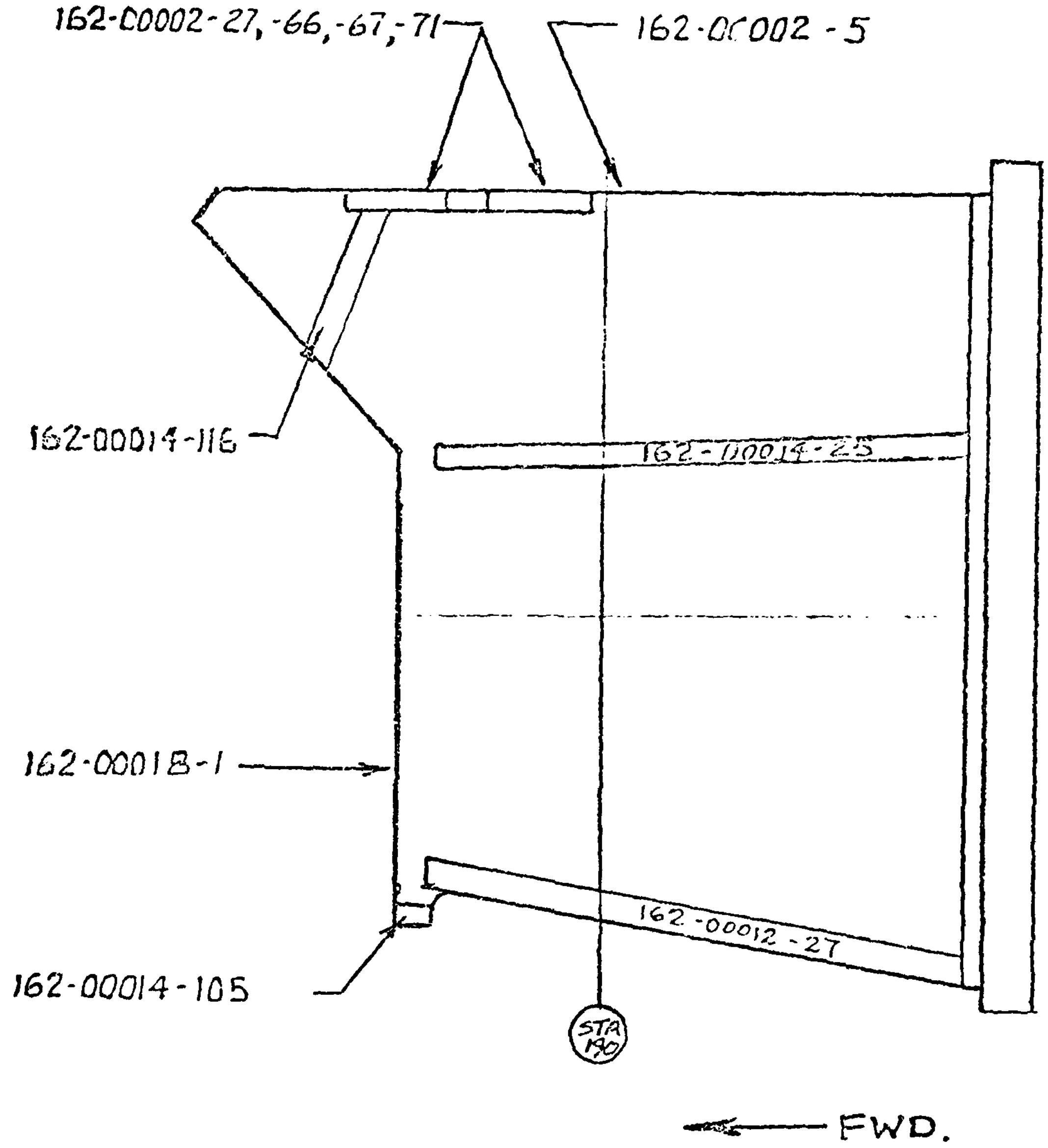
MANUFACTURING PLAN

SEE PAGE ONE FOR QUANTITY AND AUTHORIZATION

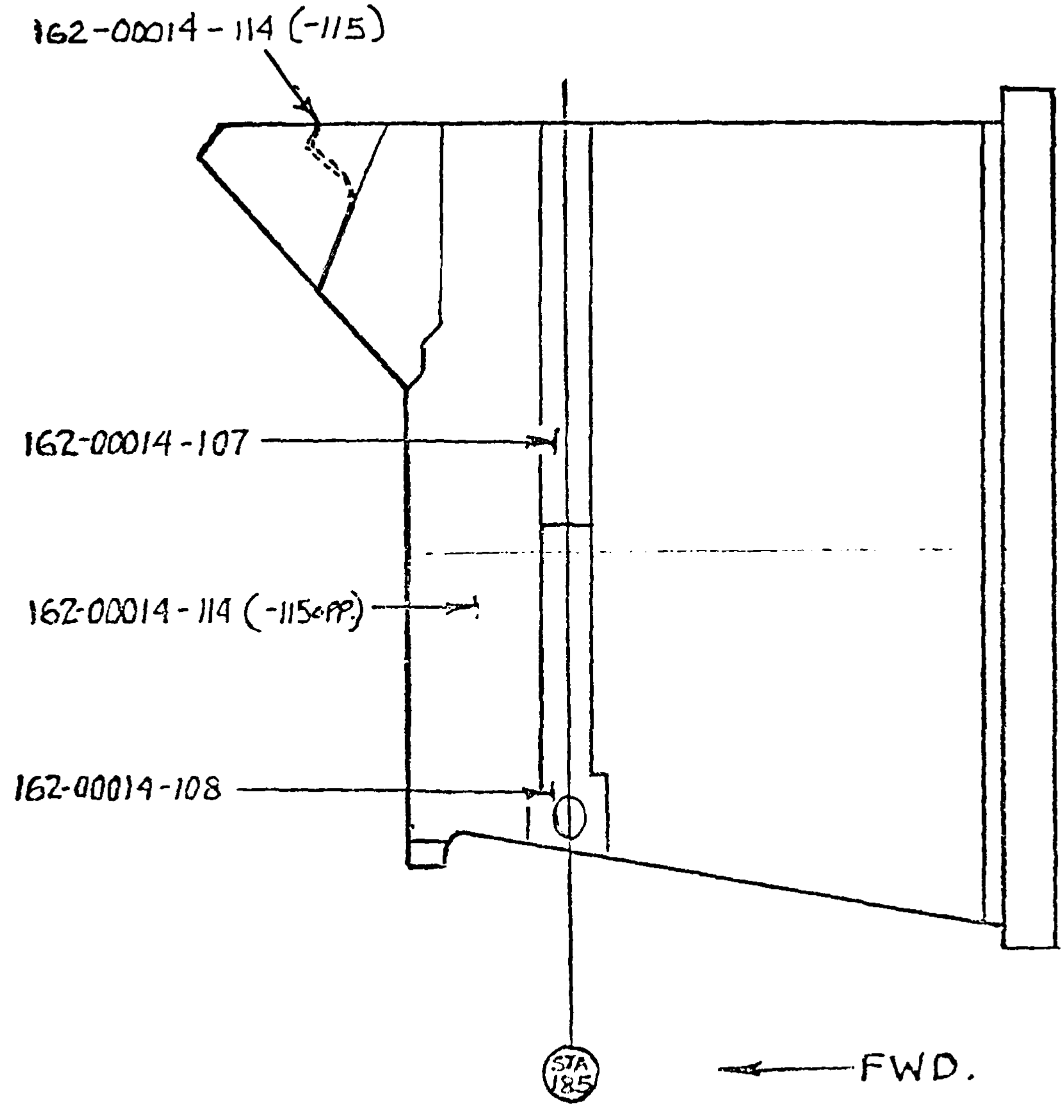
EJECTIONS	PRODUCTION SHOP & SCHEDULE	FACTORY WORK CODE	TOOL	OPERATION SEQUENCE NO	OPERATIONS & INSTRUCTIONS	LABOR STD SETUP	LABOR STD RUN	INSP SYM	INSP DATE	QTY. ACCEPT
				280	Clear this order and return the order to:					
					THE BOEING COMPANY					
					PO BOX 3707					
					SEATTLE, WASHINGTON 98124					
					Attn: Dean Kaestner					
					B-5100 Mailstop 47-56					



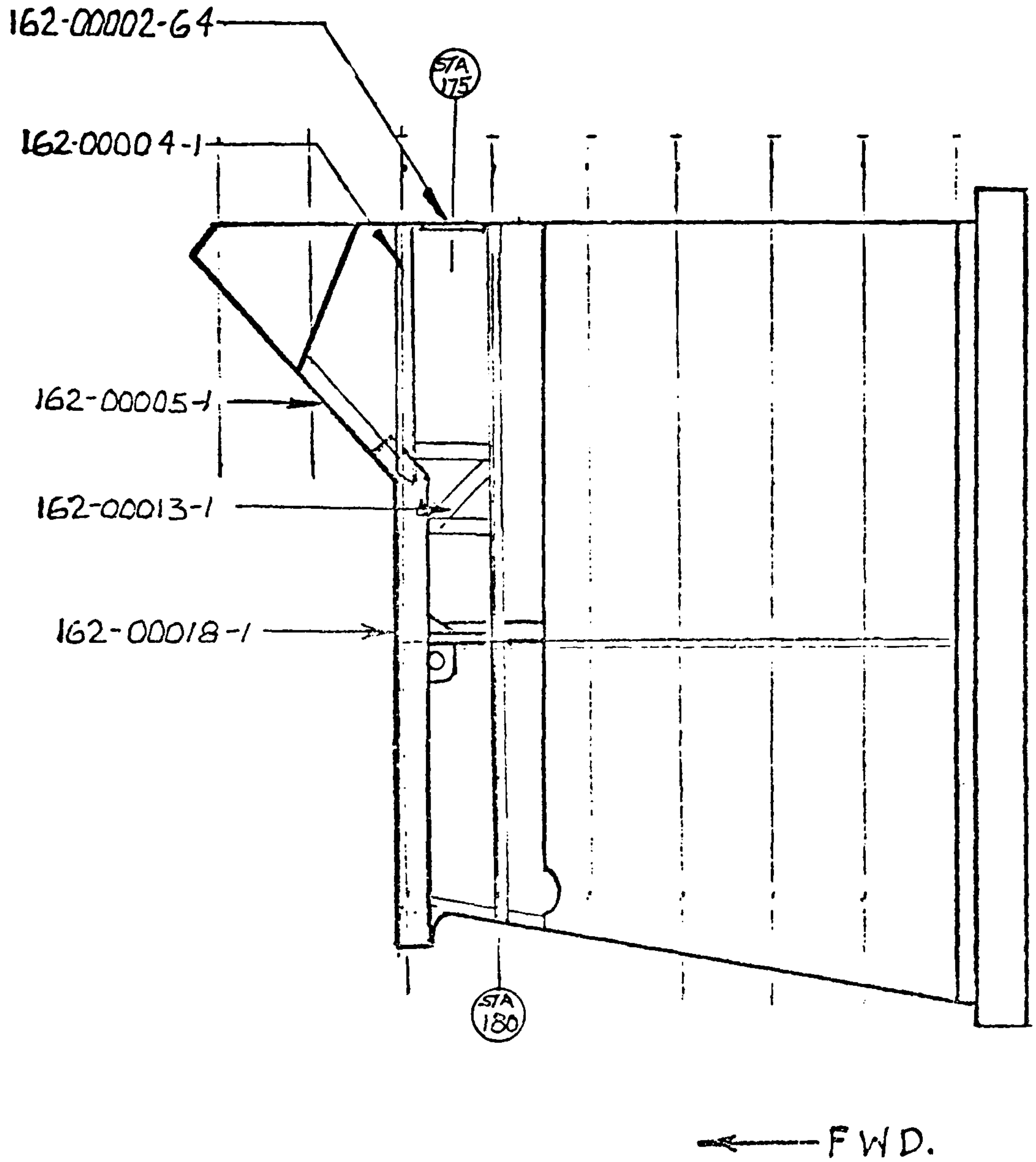
ENGR.	KAESTNER	8-8-78	REVISED	DATE	CAST BULKHEAD TEST ONLY
CHECK					SKETCH # 1
APR					
APR					BOEING



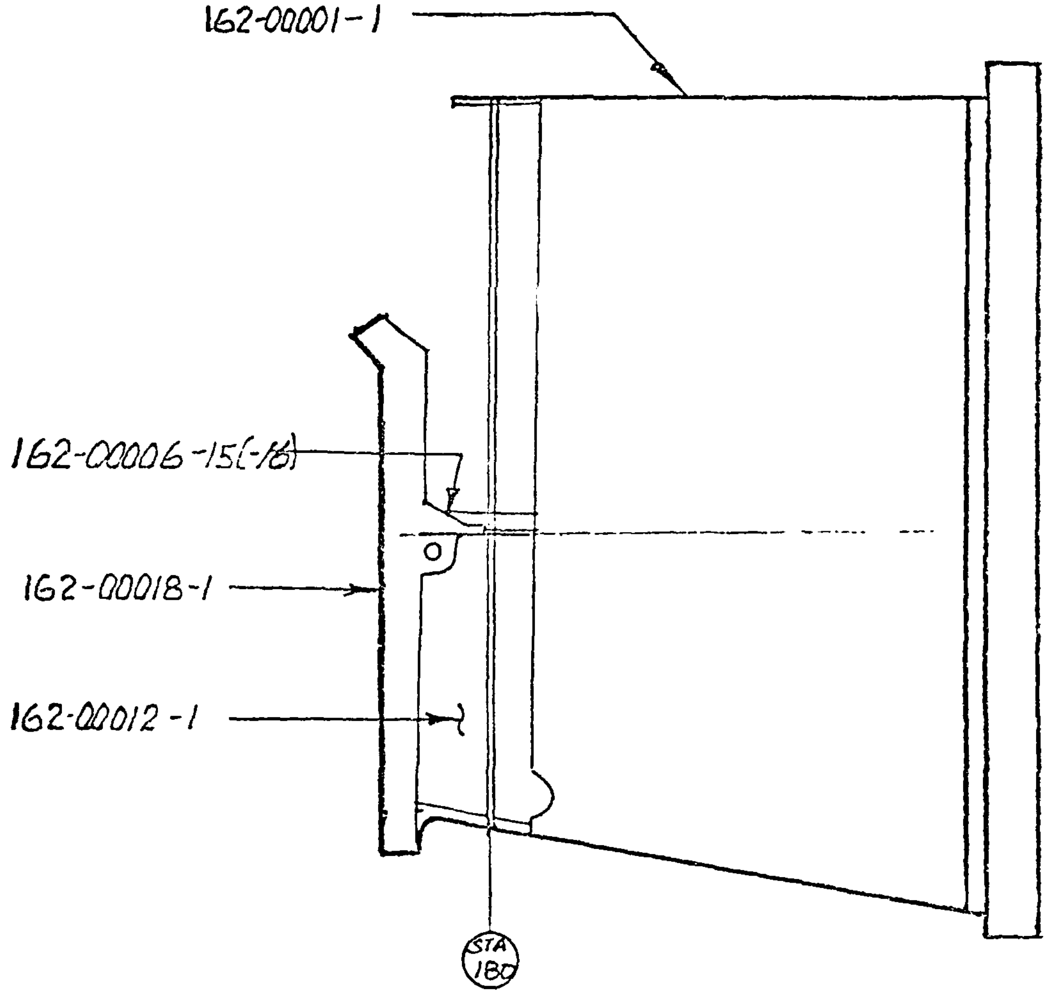
ENGR.	KAESTNER	8/18/78	REVISED	DATE	CAST BULK HEAD TEST ONLY	SKETCH
CHECK						#2
APR						
APR					BOEING	



ENGR.	KAESTNER	8/18/72	REVISED	DATE	CAST BULK HEAD TEST ONLY	SKETCH #3
CHECK						
APR					BOEING	
APR						



ENGR.	KAESTNER	6/8/75	REVISED	DATE	CAST BULK HEAD TEST ONLY	SKETCH #4
CHECK						
APR						
A R					BOEING	



ENGR.	KAESTNER	5/18/78	REVISED	DATE	CAST BULK HEAD TEST ONLY	SKETCH
CHECK						# 5
APR						
APR					BOEING	

DRAWING	SHT	4-26-7	
162-00002	1	A	
	2	A	
	3	A	
	4	A	
162-00003	1	A	
	2	A	
	3	A	
	4	A	
	5	A	
	6	A	
162-00004	1	A	
162-00005	1	A	
	2	-	
	3	A	
	4	A	
162-00006	1	A	
	2	-	
	3	-	
	4	A	
	5	A	
162-00007	1	-	
162-00008	1	-	
162-00009	1	-	
162-00010	1	-	
162-00011	1	-	
162-00012	1	A	
	2	A	
	~~3~~	(not released)	
	4	A	
162-00013	1	A	
162-00014	1	A	
	2	A	
	3	A	
	4	A	
	5	A	
162-00001	1	-	

ENGR.	KAESTNER	4-27-73	REVISED	DATE	162-00001-1 DRAWING REVISION LOG	A-17
CHECK						
APR						
APR					BOEING	

J15-047

APPENDIX D

SPECIFICATION

ALUMINUM ALLOY A357 CASTINGS,

PRIMARY AIRCRAFT STRUCTURE

M-XXXX

DRAFT

- FOR INFORMATION ONLY -
NOT TO BE USED FOR PROCUREMENT

M-XXXX

SPECIFICATION

ALUMINUM ALLOY A357 CASTINGS, PRIMARY AIRCRAFT STRUCTURE

1. SCOPE

1.1 This specification covers A357 aluminum alloy castings produced for use as primary aircraft structural components. The castings may be produced by any method approved by the procuring activity. Minimum requirements are established for destructive and nondestructive tests.

1.2 The aluminum alloy A357 castings shall be furnished in the class and mechanical property levels as specified in table I.

1.3 The casting fabricator (foundry) shall be a qualified source in accordance with Q-XXXX.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bid or request for proposa˘ form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-H-6088	-	Heat Treatment of Aluminum Alloys
MIL-I-6866	-	Inspection, Penetrant Method of
MIL-A-20695	-	Aluminum Products, Preparation for Storage and Shipment of

Cast Aluminum Structures Technology

W-XXXX	-	Welding, Fusion; Correction of Primary Structural A357 Aluminum Alloy Castings, Process for
D-XXXX	-	Aluminum Alloy A357 Castings, Dendrite Arm Spacing, Process for Determination of
Q-XXXX	-	Qualification of Foundry Contractors (Supplier) for Primary Aircraft Structural Castings
(To be added)		Inspection, Ultrasonic; Primary Aircraft Structural Castings, A357 Alloy

STANDARDS

Federal

Federal Test Method Standard No. 151

- Metals; Test Methods

Military

MIL-STD-105	-	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	-	Marking and Shipment for Storage
MIL-STD-453	-	Inspection, Radiographic

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

E8	-	Standard Method of Tension Testing of Metallic Materials
E155	-	Reference Radiographs for Inspection of Aluminum and Magnesium Castings

NATIONAL AEROSPACE STANDARDS COMMITTEE

NAS 823	-	Cast Surface Comparison Standards

3. REQUIREMENTS

3.1 Preproduction development (optional).

3.1.1 Mechanical properties shall be determined from tensile coupons excised from the castings at locations noted on the engineering drawing and in other locations as deemed necessary to determine the integrity of the castings. These locations shall be subject to the analysis for DAS per D-XXXX and results compared to requirements shown in table I.

3.1.2 The chemical composition shall be as specified in table II.

3.1.3 Ultrasonic and/or radiographic inspection techniques shall be established to verify that the integrity levels of table III are assured. Radiographic inspection shall be used for section thicknesses less than 0.75 inch and ultrasonic inspection shall be used for section thicknesses greater than 0.75 inch.

3.1.4 Dimensional inspection of preproduction castings is optional.

3.1.5 Penetrant inspection for preproduction development is optional.

3.1.6 Heat treatment may be in accordance with MIL-H-6088, except temperatures and times shall be within the ranges recommended in table IV.

3.1.6.1 Quench temperature. Quench temperature shall be recorded and monitored for each load of parts. Quench temperature and age time/temperature shall be established that provide proper mechanical properties (tensile, yield, and elongation).

NOTE: The same water volume and the same number of castings per load (stacked in the same manner) must be used each time.

3.2 First production lot qualification (required).

3.2.1 A lot of parts is defined as all castings of the same part number produced at one facility by the same production technique and submitted for inspection and acceptance at one time. A melt is defined as each single furnace melt used to make castings.

3.2.2 All castings produced to meet the requirements of this specification shall be a product that will pass the first production lot tests of this specification.

3.2.3 DAS measurements shall be performed on all castings in accordance with D-XXXX in all areas designated on the Engineering drawing for mechanical property tests. On one casting from the first lot, the mechanical properties shall be determined from all areas designated in the cast ing as well as attached (cast-on) coupons. All attached (cast-on) specimens must remain attached to the castings through all processing and be removed and tested after final heat treatment.

NOTE: The destructive test casting may have defects that are not detrimental to the test.

3.2.4 All test specimens (excised and attached or cast-on) shall meet the requirements specified in table I and the Engineering drawing. The integral (cast-on) coupons shall be removed and tested from all castings in the lot and correlated with DAS measurements obtained in 3.2.3.

3.2.5 All castings shall be ultrasonic and/or radiographically inspected to the criteria specified in table IV and 3.1.3. The severity of the imperfections shall be graded per D-XXXX and compared to table III for the applicable properties specified on the drawing. Imperfections revealed by the radiograph of the casting shall be matched to the comparable ASTM E-155 reference radiograph for a particular imperfection. Imperfections exceeding the limits of table III shall be classified as defects and are unacceptable. Castings containing defects may be corrected by welding in accordance with W-XXXX and reinspected.

3.2.6 Heat treatment shall be performed on whole castings, and never on a portion only, in accordance with the requirements of MIL-H-6088 except that times and temperatures may be within the range recommended in table IV.

3.2.6.1 Quench temperature and age time/temperature shall be established per 3.1.6.1. Water volume and furnace load shall be maintained constant.

3.2.7 Each casting shall be 100 percent visually and penetrant inspected. The surfaces shall not contain laps, cold shuts, seams, linear porosity, or inclusions. When such defects are found, the casting may be corrected by welding as allowed in 3.2.5.

3.2.8 Surface finish shall be compared with NAS 823 as specified on the engineering drawing and shall be well-cleaned. A metallic abrasive shall not be used for final cleaning. Special attention shall be paid to where gates and risers have been removed.

3.2.9 Each casting shall be dimensionally inspected for compliance with drawing requirements.

3.2.10 One spectrochemical test from each melt shall be prepared and submitted for spectrographic chemical analysis to the requirements specified in table I after degassing and before pouring. Additionally, integral cast spectrochemical discs may be required by drawing and subsequently analyzed.

3.3 Production castings.

3.3.1 Subsequent to the acceptance of the first production lot of parts, any modification of the casting, or change in the method of manufacture that, in the opinion of the procuring activity, could adversely affect any casting characteristic, shall require destructive testing of a casting made incorporating such changes. Destructive testing shall be in accordance with paragraphs 3.2.3 and 3.2.4.

3.3.2 Subsequent to the acceptance of the first production lot, mechanical property and DAS tests for routine production testing in accordance with this specification will utilize the attached (cast on) coupons and the DAS grading measurements of D-XXXX. In addition, the first, eleventh, and twenty-fifth castings shall be destructively tested. Subsequently, one casting in every 50 castings shall be destructively tested.

NOTE: The destructive test castings may have defects that are not detrimental to the test. However, test castings must have serial numbers within $\pm$ 2 to the sample numbers designated above in 3.3.2.

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3.3.3 Spectrographic chemical testing of one sample for each melt is required and the chemistry of the melt shall meet the limits specified in table II after degassing and before pouring. Additionally, integral cast spectrochemical discs may be required by drawing and subsequently analyzed.

3.3.4 Radiographic inspection is to be conducted to the requirements of paragraph 3.2.5 except that the critical areas of all castings shall be 100 percent radiographically examined.

3.3.5 Heat treatment is to be conducted to the requirements of paragraph 3.2.6 and 3.2.6.1.

3.3.6 All castings shall be penetrant inspected. Surface finish shall be compared to NAS 823 and the engineering drawing.

3.3.7 Identification of product. Each casting shall be identified with the part number by the use of raised numerals in a location indicated on the drawing. Serial numbers shall be provided for each casting in a location shown on the drawing. When no location is shown on the drawing, the numbers shall be so located as not to be machined off in finishing to the required dimensions. The serial number shall be traceable to the casting melt and heat treat lot, mechanical properties, and NDE reports.

3.3.7.1 Castings on which it is impractical to provide raised numerals shall be marked in accordance with the procuring activity's requirements.

3.3.8 Dimensions. The dimensions of the castings shall be within the dimensions and tolerances specified on the applicable drawings.

3.3.9 Workmanship. Castings shall be uniform in quality and condition, sound, clean, and substantially free from foreign materials.

4. QUALITY ASSURANCE PROVISIONS

4.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the procuring activity. The procuring activity has the right to perform any of the inspections set forth in the specifications where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of tests. The inspection and testing of castings shall be classified as follows:

(a) Preproduction tests -- see 3.1.

(b) First production lot qualification -- see 3.2.

(c) Production quality conformance tests -- see 4.4.

4.3 Preproduction tests.

4.3.1 Sampling instructions. The first castings produced shall be the optional preproduction test samples (see 3.1) and shall comply with the requirements of this specification. Samples shall be identified as required by the procuring activity for acceptance procedure.

4.3.2 Preproduction testing. Preproduction testing of the aluminum alloy castings shall consist of all tests described under Test Methods, 4.6, for all the requirements specified in Section 3.1 of this specification.

4.4 First production lot. Testing shall consist of all tests as described under 3.2.

4.5 Quality conformance tests. Quality conformance tests shall consist of all tests as described under 4.6.

4.5.1 Visual and dimensional examination. A random sample shall be selected from each lot in accordance with Military Standard MIL-STD-105, Inspection Level II, Acceptable Quality Level 2.5 percent defective.

4.5.2 Chemical composition. A sample shall be tested from each melt after all processing has been completed and the temperature of the melt is satisfactory to pour the casting. Additionally, integral cast spectrochemical discs may be required by the drawing and subsequently analyzed.

4.5.2.1 Preparation of sample specimens for the chemical analysis shall be in accordance with method 111.1 or method 112.1 of Federal Test Method Standard No. 151.

4.5.2.2 The sample for spectrographic analysis may be taken from a broken tensile specimen. If a separate sample is used, it shall conform to the requirements of Federal Test Method Standard No. 151. It shall weigh approximately 20 grams.

4.5.3 Radiographic and/or ultrasonic and penetrant inspection. All castings shall be radiographically and/or ultrasonically and penetrant inspected. Section 3.1.3 defines thickness criteria for radiographic and ultrasonic inspection.

4.5.4 Mechanical properties. Attached (cast-on) coupons shall be removed and tested from each casting.

4.5.5 DAS measurements shall be made on all castings and correlated with measurements obtained per paragraphs 3.2.3 and 3.2.4.

4.6 Test methods.

4.6.1 Chemical composition. Analysis shall be by spectrographic or chemical methods in accordance with methods 111.1 or 112.1 of Federal Test Method Standard No. 151. In case of dispute, the chemical analysis by wet chemical methods shall be the basis for acceptance.

4.6.2 Radiographic inspection. This examination shall be conducted in accordance with Military Standard MIL-STD-453. The limits of X-ray indications shall, unless otherwise noted, be as specified in 3.2.5. Additional radiographic inspection may be specified by the procuring activity.

4.6.2.1 Ultrasonic inspection. (To be added)

4.6.3 Pentrant inspection. Each casting shall receive 100 percent inspection in accordance with MIL-I-6866.

4.6.4 Mechanical properties. The tension test specimen shall conform to ASTM E8. When the size or shape of the casting restricts the use of the above test specimens, or when otherwise determined, the full-size casting may be tested. When a complete casting test is required, the strength requirement and the direction or method of loading of the full-size casting shall be specified on the drawing for the part concerned.

4.6.5 Visual and dimensional examination. Each casting shall be examined for surface imperfections, identification of product, dimensions, and workmanship requirements of 3.3.

4.6.6 Preservation, packing, and marking. Preservation, packing, and marking shall be examined for conformance with section 5 of this specification.

4.7 Rejection and retest. Failure of any specimens to conform to any one of the requirements of this specification shall be cause for rejection of the represented casting. Retest will be permitted in accordance with Federal Test Method Standard No. 151.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packing. All castings shall be preserved and packed in accordance with the requirements of Specification MIL-A-20695. The procuring acitivity will specify the levels required (see 6.2).

5.2 Marking of shipments. Each shipping container shall be marked in accordance with Standard MIL-STD-129.

6. NOTES

6.1 Intended use. The high strength aluminum alloy castings covered by this specification are intended for use in airframe, missile, and other applications where high strength and reliability are required.

6.2 Ordering data. Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Alloy number, grade, and class of castings (see 1.2).

(c) The applicable drawings.

(d) Level of packing desired (see 5.1).

(e) Any other options desired.

(f) Where the results of preproduction tests should be sent, the activity responsible for testing, and instructions concerning submittal of the test reports (see 3.1).

TABLE I. MINIMUM MECHANICAL PROPERTY REQUIREMENTS, A357-T6 ALUMINUM ALLOY CASTINGS

Class	Tensile Strength (ksi)		Yield Strength at 0.2 percent Offset (ksi)		Elongation in 2 inches or 4D (percent)	
	Critical Areas (1)	Other Areas	Critical Areas (1)	Other Areas	Critical Areas (1)	Other Areas
1	50	40	40	30	5	3

NOTE:

(1) Critical areas are defined on the Engineering Drawing as shown:

IF NO CRITICAL AREAS ARE SHOWN, THE ENTIRE CASTING SHALL BE CONSIDERED AS "OTHER AREAS."

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TABLE II. CHEMICAL COMPOSITION LIMITS,
A357 ALUMINUM ALLOY

Elements	Percent, Minimum	Percent, Maximum
Copper	--	0.20
Silicon	6.5	7.5
Iron	--	0.10
Manganese	--	0.10
Zinc	--	0.10
Magnesium	0.55	0.65
Titanium	0.10	0.20
Beryllium	0.04	0.07
Others, each	--	0.05
Others, total	--	0.15
Aluminum	Remainder	

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TABLE III. MAXIMUM SEVERITY OF RADIOGRAPHIC IMPERFECTIONS

		Radiographic Standard of Maximum Acceptable Defects in Accordance with ASTM E155-60			
		Grade B (1) (Critical Areas)		Grade C (Other Areas)	
Radiographic Imperfections	Radiographic Reference Film	thru 1/2 in.	over 1/2 in.	thru 1/2 in.	over 1/2 in.
Gas Holes	1.1	1	1	2	2
Gas Porosity (Round)	1.21	1	1	3	3
Gas Porosity (Elongated)	1.22	1	2	3	4
Shrinkage Cavity	2.1	1	Not avail. (6)	2	Not avail. (6)
			1		1
Shrinkage Porosity or Sponge	2.2	1	1	2	2
Foreign Material (Less Dense)	3.11	1	1	2	2
Foreign Material (More Dense)	3.12	None	None	2	1
Segregation	--	None		None	
Cracks	--	None		None	
Cold Shuts	--	None		None	
Misruns	--	None		None	
Surface Irregularities	--	Drawing Tolerance		Drawing Tolerance	
Core Shift	--				

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TABLE III (Continued)

NOTES:

(1) Critical areas are defined on the Engineering Drawing as shown:

(2) When two or more types of defects are present to an extent equal to or not significantly better than the acceptance standards for respective defects, the parts shall be rejected.

(3) When two or more types of defects are present and the predominating defect is not significantly better than the acceptance standard, the part shall be considered borderline.

(4) Borderline castings shall be reviewed for acceptance or rejection by the "designated" foundry engineer and the procuring activity quality control.

(5) Gas holes or sand spots and inclusions allowed by this table shall be cause for rejection when closer than twice their maximum dimension to an edge or extremity of a casting.

(6) If shrinkage cavity discontinuities appear on radiographs, castings shall be dispositioned by the procuring activity.

TABLE IV. HEAT TREATMENT RECOMMENDATIONS, A357-T6 ALUMINUM ALLOY CASTINGS

Solution Heat Treatment	Quench Delay	Quenchant	Natural Aging	Precipitation Heat Treatment (Aging)
1010°F ± 10°F for 16 hrs. min. [1]	8 sec. max.	170°F ± 30°F water	Room temp. for 16-24 hrs.	325°F ± 10°F for 8 hrs. ± 1 hr.

1 For castings with 1 inch maximum thickness. Add 2 hours soak for each additional 1/2 inch thickness.

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APPENDIX E

SPECIFICATION

WELDING, FUSION, CORRECTION OF PRIMARY STRUCTURAL

A357 ALUMINUM ALLOY CASTINGS, PROCESS FOR

W-XXXX

SPECIFICATION

WELDING, FUSION, CORRECTION OF PRIMARY STRUCTURAL
A357 ALUMINUM ALLOY CASTINGS, PROCESS FOR

1. SCOPE

This specification covers the use of fusion welding for the correction of manufacturing imperfections in primary structural A357 aluminum alloy castings. The following fusion welding processes are involved:

(a) Gas Tungsten Arc Welding; Direct Current-Straight Polarity (GTAW-DCSP).

(b) Gas Tungsten Arc Welding; Alternating Current (GTAW-AC).

(c) Gas Metal Arc Welding; Direct Current-Reverse Polarity (GMAW-DCRP).

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect at the date of invitation for bid shall form part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

O-A-51	-	Acetone, Technical
TT-N-95	-	Naphtha, Aliphatic
TT-M-261	-	Methyl Ethyl Ketone, Technical
QQ-R-566	-	Rods and Electrodes, Welding Aluminum Alloys
TT-I-735	-	Isopropyl Alcohol
BB-O-925	-	Oxygen, Technical, Gas and Liquid
BB-H-1168	-	Helium, Technical

Cast Aluminum Structures Technology

M-XXXX	-	Aluminum Alloy A357 Castings, Primary Aircraft Structure

Military

MIL-T-5021	-	Tests, Aircraft Welders and Welding Operators Certification
MIL-H-6088	-	Heat Treatment of Aluminum Alloys
MIL-I-6866	-	Inspection, Penetrant, Method of
MIL-A-18455	-	Argon - Technical, Gas and Liquid

STANDARDS

MIL-STD-453	-	Inspection, Radiographic

OTHER PUBLICATIONS

American Welding Society

AWS 5.12	-	Tungsten, Arc Welding Electrodes

3. REQUIREMENTS

3.1 Equipment.

3.1.1 General. The welding equipment, such as welding machines, welding torches, regulators, flow meters, and filler metal feed mechanisms, shall be capable of making satisfactory welds when operated by a certified welder using the filler metal specified in 3.2.

3.1.1.1 Verification of equipment function. If, for any reason, the procuring activity representative doubts the capability of any welding equipment to function properly, he may require that verification tests be conducted using the questionable equipment.

(a) The verification tests shall be selected by the representative from applicable tests specified in MIL-T-5021 or as he may otherwise specify.

(b) The tests shall be performed by welder(s) certified for A357 cast aluminum alloy on the specific type of equipment in question and shall be selected by the representative.

(c) If the results of these tests do not meet the requirements of MIL-T-5021, the questionable welding equipment shall not be used for welding on production castings until the necessary adjustments, repairs, or replacements have been made, and a second set of verification tests indicates satisfactory results.

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3.1.2 Heating and cooling facilities.

3.1.2.1 Furnaces. Furnaces used for preheating castings prior to welding shall have suitable pyrometric controls as required by MIL-H-6088.

3.1.2.2 Cooling ovens. Cooling ovens shall be provided with suitable means for controlling the cooling rates to prevent damage to castings that have been preheated prior to corrective welding. Preheating furnaces may be used as cooling ovens providing they are capable of cooling rate control.

3.1.3 Prewelding preparation tools. Chipping, drilling, machining, gouging, and scraping tools used in the preparation of areas of castings for welding shall be kept sharp, clean, and otherwise maintained in good condition.

3.1.4 Protective equipment. Suitable protective equipment such as face shields, goggles, gloves, aprons, and ventilation facilities shall be used to protect personnel as may be required by the specific locality for the operation performed.

3.1.4.1 Ventilation equipment. Ventilation shall be provided in the welding area to protect all personnel from welding fumes and gases. Special precautions must be taken in the location and operation of such equipment to assure that the inert gas shielding envelope required to protect welds from atmospheric contamination is not disrupted.

3.2 Materials.

3.2.1 Filler metals.

(a) The as-deposited chemistry of filler metal used in the welding of castings shall conform to the nominal chemical composition of M-XXXX A357 aluminum alloy castings.

(b) Weld filler metal may be procured as wire in 36-inch lengths or continuous lengths procured level wound on spools.

3.2.2 Bare tungsten electrodes. Bare tungsten electrodes for GTAW shall conform to the requirements of table I.

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TABLE I. BARE TUNGSTEN ELECTRODES 1

Classification		Procurement Specification	Usage 2	AWS Color Code 3
AWS Class	Type			
EWTh-2	2% thoriated	AWS 5.12 class EWTh-2	Preferred for DCSP GTAW	Red
EWZr	Zirconium	AWS 5.12 class EWZr	Preferred for AC GTAW	Brown

1 Bare tungsten electrodes are classified on the basis of chemical composition.

2 Unless otherwise specified in the certified procedure, the selection of the proper tungsten electrode is the user's option.

3 Color coding is required and may be applied in the form of bands or dots, etc. at any place on the electrode, but the color material shall not cause adverse effects (such as porosity) on welds.

3.2.3 Shielding gases. Shielding gases used in the corrective welding of A357 castings shall be as specified in table II.

TABLE II. SHIELDING GASES

Gases	Specifications
Argon	MIL-A-18455
Helium	Federal Specification BB-H-1168 Grade A
Oxygen	Federal Specification BB-O-925 Type I or Type II
Gas Mixtures	Purity of gases in mixtures shall be as specified for the individual gas.

3.2.4 Solvents. The cleaning and degreasing solvents listed in table III may be used for final cleaning prior to welding.

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TABLE III. SOLVENTS

Solvent	Federal Specification
Acetone, technical	O-A-51
Aliphatic naphtha	TT-N-95
Methyl-ethyl ketone (MEK)	TT-M-261
Isopropyl alcohol	TT-I-735

3.2.5 Wire brushes. All wire brushes used in the precleaning or descaling operations prior to welding and after welding shall be of the AISI 300-series stainless steels and be maintained free from contaminants at all times by degreasing with one of the solvents listed in table III.

3.3 Required procedures and operations.

3.3.1 Casting preweld heat treat conditions. See 3.4.3 for recommended procedures.

3.3.2 Preweld preparation. In the area to be welded, all defective material shall be completely removed by an appropriate method such as drilling, chipping, scraping, machining, gouging, etc.

(a) The prepared area shall be made larger at the surface of the casting by sloping the sides at not less than 15° with the vertical to the cast surface. This is necessary to achieve proper sidewall fusion for the depth of the hole.

(b) The resulting surfaces on the prepared area shall be as free from sharp grooves, burrs, and feathery edges as practical.

(c) The "as-cast" surface for a distance of at least one inch from the prepared area shall be removed by light scraping or wire brushing to remove scale oxides, imbedded sand, etc. to avoid contamination of the weld bead as it fairs into the casting.

(d) All areas prepared for welding shall be carefully inspected by visual and penetrant methods to assure that defects such as cracks have been completely removed.

(e) Immediately prior to welding, all prepared area surfaces and the surrounding area for at least two inches away shall be thoroughly degreased using one of the solvents listed in table III. After degreasing, the area shall be dried by using a clean lint-free cloth or by blowing with dry, oil-free air.

3.3.3 Preheating. When preheating is necessary to control porosity, cracking, etc., a temperature range of 150-300°F shall be used. The preheat temperature shall be maintained between passes during welding.

3.3.3.1 Method of heating.

(a) The use of a furnace or oven as specified in 3.1.2 for preheating is preferred.

(b) When it is not practical to place a large casting in a furnace or oven, preheating and interpass temperatures may be accomplished by the use of a gentle, soot-free flame. When a flame is used, the temperature gradient should be wide-spread and suitable pyrometric controls such as a pyrometer, temperature indicating sticks or liquid, etc. shall be employed. Care shall be exercised to avoid contaminating the intended weld area.

3.3.4 Weld fixtures. Weld fixtures that may be required for distortion control shall be kept clean and free from contaminants.

3.3.5 Welding. Welding shall be accomplished only by a certified welder using certified procedures in accordance with 3.5.

3.3.5.1 Welding processes. Only those processes allowed in 1. shall be used.

3.3.5.2 Weld shielding gases. The weld shielding gases used for repair welding shall conform to 3.2.3 table II. The exact gas or mixture and its flow rate shall be as developed and recorded on the approved welding procedure in accordance with the following requirements:

(a) For GTA DCSP welding, the shielding gas shall be helium or helium-argon mixtures.

(b) For GTA AC welding, the shielding gas shall be argon or argon-helium mixtures.

(c) For GMA DCRP welding, the shielding gas may be argon, helium, argon-helium mixtures, argon with small percentages of oxygen, or argon-helium with small percentages of oxygen.

3.3.6 Postweld cooling. Cooling of castings after welding shall be accomplished slowly at a controlled rate to avoid distortion and possible cracking.

3.3.6.1 Oven or still air cooling. The use of a suitable furnace or oven as specified in 3.3.3 is preferred. However, in cases where preheating was done locally or it is impractical to place the casting in a furnace or oven, the casting shall be cooled in still air at room temperature or covered with a thermal insulating blanket.

3.3.7 Heat treatment. Except as allowed in 3.3.7.1, all castings shall be heat treated after welding to drawing and M-XXXX requirements in accordance with the general procedures outlined in MIL-H-6088.

3.3.7.1 As-welded condition. When they are identified on the drawing, certain areas of heat treated castings may be welded without post welding reheat treatment.

3.3.8 Smoothness and weld contour. All welds shall fair into the adjacent metal in gradual, smooth transitions. Beads shall be smooth and free of slag, undercut, and excessive spatter. Sufficient weld metal shall be added to form a suitable fillet or backup. Excess metal shall be removed by shaving, machining, etc. in such a manner as not to create obscure defects that will show up during penetrant inspection.

3.3.9 Weld quality. All welds shall meet the nondestructive test requirements specified in 4.2.2.

3.3.10 Marking of welded castings. Each individual welded area of a casting shall be marked with the welder's identification number in a manner such that it will remain on the casting until it has passed final inspecton or permanently, depending upon the customer requirements.

3.4 Recommended procedures and operations.

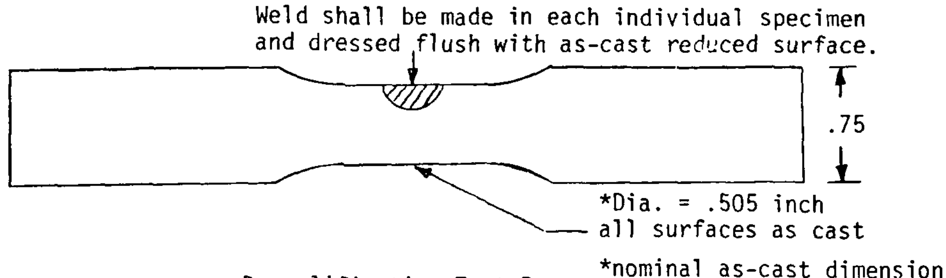
3.4.1 Feasibility of correction by welding. The overall number and size of welds required on any one casting should be considered to determine if welding is economically feasible.

3.4.2 Additional NDT methods. Prior to welding, the prepared area may be inspected with additional nondestructive methods such as radiography, ultrasonics, or eddy current as necessary to assure that cracks have been completely removed and not just "smeared over" during defect removal.

3.4.3 Casting preweld heat treat conditions. Whenever possible, welding should be accomplished only on castings in the "as-cast" or solution treated conditions. However, if it can reasonably be determined that satisfactory welds can be obtained in specific instances, welding may be performed on aged castings. Consideration for re-heat treating after welding shall be given in accordance with 3.3.7.

3.5 Certification of welds and welding procedures.

3.5.1 Welders certification. All welders shall be certified for aluminum alloys in accordance with MIL-T-5021, class A for each process to be used in production. Recertification shall be required every six (6) months using a joint seven weld except a cast A357 test bar shall be used in lieu of the normal test piece. See figure 1.



Requalification Test Bar

Figure 1

Weld samples will be checked in accordance with MIL-T-5021. All X-rays and certification shall be retained on file and letter of certification shall be sent to the customer upon request.

3.5.2 Welding procedure certification. The welding procedures used for the correction of M-XXXX primary structural aluminum alloy casting produced by each contractor shall be certified. Certification will be accomplished on the first production lot of welded M-XXXX castings by the contractor demonstrating to the procuring activity by means of the tests required in 4. that the quality of the welded casting meets the requirements of 4.2.2(b).

3.5.2.1 No castings containing welds may be delivered until certification procedures have been granted in writing by the procuring activity or their representative.

4. QUALITY ASSURANCE PROVISIONS

4.1 Sampling, inspection, and tests.

4.1.1 General. All welded M-XXXX A357 aluminum alloy structural castings shall be subject to inspection by the authorized procuring activity representative or his designee who shall be given reasonable facilities to determine conformance with the requirements of this specification.

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AD-A078 854 BOEING AEROSPACE CO SEATTLE WA F/G 11/6
CAST ALUMINUM STRUCTURES TECHNOLOGY (CAST). PHASE IV. FABRICATI--ETC(U)
MAR 79 R C MCFIELD , L A LOGAN , J W FABER F33615-76-C-3111
UNCLASSIFIED D180-24610-1 AFFDL-TR-79-3029 NL

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4.2 Sampling.

4.2.1 Welding procedure certification sampling. For consideration of procedures approval, the procuring activity representative shall select sufficient welded castings from the first lot of production parts to establish that the quality of the welded castings meets the requirements of 4.2.2(b). Insofar as practical, he shall select castings welded by different welders.

4.2.1.1 Procedure information and data. The following information, as applicable, shall be furnished with all welded castings submitted for consideration of approval of procedures.

(a) Foundry or company doing the welding.

(b) Date welding was accomplished.

(c) Welding process (GTAW DCSP, GTAW AC, GMAW DCRP).

(d) Manufacturer, type and serial number of welding machine, and torch.

(e) Type and purity of shielding gas (mixture percentages), flow rates, etc.

(f) Filler wire composition and specification.

(g) Methods of preweld preparation (chipping, scraping, machining, drilling, etc.).

(h) Preheat and interpass temperatures and method of application of heat for each.

(i) Postwelding method of cooling (oven or blanket), and rate.

(j) Postweld heat treat condition.

(k) Welder's name and identification number.

(l) Sketch of remanufactured casting showing welded areas (schematic).

(m) Method of nondestructive inspection used after welding.

(n) Data from destructive tests (if required by procuring activity representative).

(o) Company inspector name and stamp.

4.2.2 Production inspection.

(a) All welded castings shall be subjected to 100% inspection after heat treat using the inspection method(s) required for the casting by drawing and M-XXXX. If reheat treating is not required, only the weld and area within one inch of the weld need be inspected.

(b) All welded castings shall meet the quality requirements specified on the drawing and in M-XXXX for the casting.

4.3 Test methods.

4.3.1 Radiographic inspection. Radiographic inspection shall be performed in accordance with the procedures specified in MIL-STD-453 and as specified on the applicable drawing or in M-XXXX.

4.3.2 Penetrant inspection. Penetrant inspection shall be performed in accordance with MIL-I-6866 and as specified by the drawing and M-XXXX.

4.3.3 Destructive testing. The preparation of such microscopic and macroscopic specimens as may be required by the procuring activity representative to aid in evaluating preliminary welding techniques for production procedure and welder certification shall be in accordance with standard metallurgical practice. Microscopic examination shall be at 100 diameters magnification or higher.

4.3.4 Inspection responsibilities. Unless otherwise specified in the contract or purchase order, contractors are responsible for the performance of all inspection requirements as specified herein. Contractors shall have laboratory facilities for conducting the metallurgical, radiographic, penetrant, and other such test methods that are to be used to evaluate remanufactured casting quality. The contractor may, if he does not have the required facilities, engage those commercial laboratories necessary providing they are approved by the procuring agency.

4.3.5 Optional methods of inspection. The contractor may employ additional methods of inspection, such as ultrasonic and eddy current, that may not be specified on the drawing, to aid in determining the true nature of discontinuities.

5. This section is not applicable to this specification.

6. NOTES

6.1 Intended use. The process described by this specification is intended for use only in the correction of manufacturing imperfections in M-XXXX aluminum alloy A357 structural aircraft castings by fusion welding.

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APPENDIX F

SPECIFICATION

ALUMINUM ALLOY A357 CASTINGS, DENDRITE

ARM SPACING, PROCESS FOR DETERMINATION OF

D-XXXX

SPECIFICATION

ALUMINUM ALLOY A357 CASTINGS, DENDRITE ARM SPACING, PROCESS FOR DETERMINATION OF

1. SCOPE

1.1 This specification covers the procedures for determining the dendrite arm spacing (DAS) in M-XXXX A357 aluminum alloy castings in either the as-cast or heat treated condition.

1.2 This is a nondestructive test method for examining surface metallographic features of a casting to aid in the determination of its acceptability.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect at the date of invitation for bid shall form a part of this specification to the extent specified herein.

SPECIFICATIONS

Cast Aluminum Structures Technology

M-XXXX - Aluminum Alloy A357 Castings, Primary Aircraft Structure

3. REQUIREMENTS

3.1 Equipment.

3.1.1 General. The testing equipment, such as polishing, replicating, and microscopic equipment, shall be capable of satisfactorily performing the required functions when operated by qualifed personnel using the proper techniques.

3.1.2 Polishing equipment.

3.1.2.1 Portable polishing unit. Transpol (Max Erb Instrument Co.) or equivalent.

3.1.2.2 Electropolishing unit. Movipol (Max Erb Instrument Co.) or equivalent.

3.1.3 Microstructure replicating equipment. Transcopy (Max Erb Instrument Co.) or equivalent.

3.1.4 Photomicrographic equipment. Light microscope with camera attachment.

3.1.5 Hand-held 100X microscope with through-the-lens lighting.

3.2 Materials.

3.2.1 Grinding and polishing materials.

3.2.1.1 Abrasive paper, 100 through 600 grit.

3.2.1.2 Diamond polishing compound, 15, 6, 3, and 1/4 micron.

3.2.1.3 Electropolishing solution. The recommended polishing solution for Movipol or equivalent equipment is as follows:

Distilled water	120 ml
Tartaric acid	50 g
Ethyl alcohol	100 ml
Butyl cellosolve	100 ml
Perchloric acid (60%)	78 ml

3.2.2 Etching materials.

3.2.2.1 Electroetching solution. The recommended etching solution is the same as the polishing solution in 3.2.1.3.

3.2.2.2 Chemical etching solutions.

3.2.2.2.1 Hydrofluoric acid, 0.5%.

3.2.3 Replicating materials.

3.2.3.1 Plastic replica.

3.2.3.2 Replicating tape.

3.3 Required procedures and operations.

3.3.1 DAS test locations.

3.3.1.1 Castings. The location of DAS measurements shall be on one chilled surface (when chills are used) of the casting as close as possible to the center of the tensile coupon location as shown on the Engineering drawing. See example in figure 1.

3.3.1.2 Integral cast-on coupons. A DAS measurement shall be taken on one chilled surface (when chills are used) at the center of each integral cast-on coupon. See example in figure 1.

3.3.1.3 DAS measurements shall also be made on the surface of the tensile specimen grip prior to tensile testing during preproduction evaluation per M-XXXX.

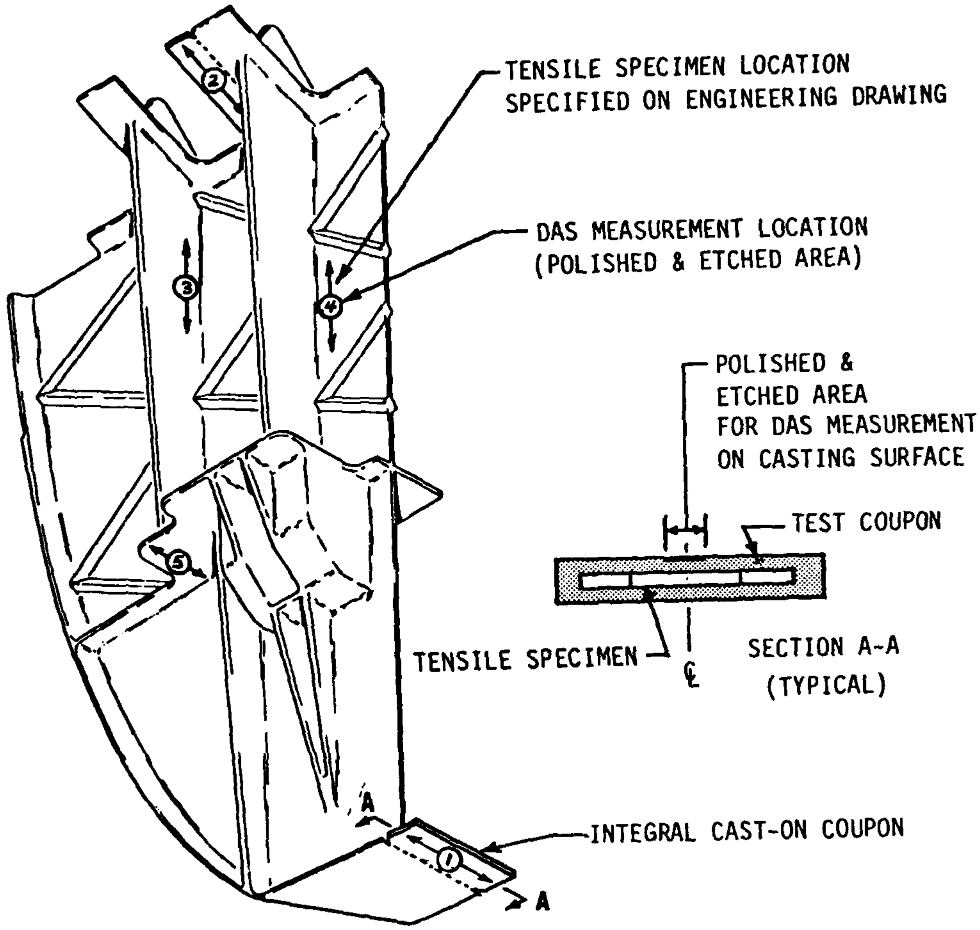

FIGURE 1. TEST LOCATIONS

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3.3.2 DAS test procedure.

3.3.2.1 Test location preparation. Surface preparation for all DAS measurements shall consist of prepolishing, final polishing, and etching to reveal the microstructure.

a. Microstructure shall clearly distinguish the secondary dendrite arm spacing of the casting. Secondary dendrite arm spacing is illustrated schematically in figure 2.

b. If the test location is improperly polished, underetched, or overetched, it shall be repolished very lightly using the 400-600 grit paper specified in 3.2.1.1 and re-etched. Underetched locations shall not be re-etched without repolishing.

3.3.2.1.1 Prepolishing. Test locations shall be prepolished by grinding or sanding using the equipment specified in 3.1.2.1 with the 100 grit paper followed by the 400-600 grit paper specified in 3.2.1.1. Prepolishing should not remove more than 0.005 inch from the surface of the test location, but shall be sufficient to allow final polishing and etching to produce a detailed outline of the secondary dendrite arm spacing.

3.3.2.1.2 Final polishing. Prepolished test locations shall be given a final polishing using either a mechanical polishing or an electropolishing method.

a. Mechanical polishing shall be performed using the equipment specified in 3.1.2.1 and the materials specified in 3.2.1.2.

b. Electropolishing shall be performed using Movipol electropolisher or equivalent equipment specified in 3.1.2.2. The recommended polishing solution is listed in 3.2.1.3.

3.3.2.1.3 Etching. Etching shall be accomplished either by the chemical method or by electroetching.

a. Chemical etching shall be performed by swabbing the polished area with 0.5% hydrofluoric acid. Care must be exercised to prevent the etchant from coming into contact with other areas of the casting. Upon completion of etching, the area must be rinsed thoroughly with distilled water until all etchant is removed. The test area shall then be thoroughly dried.

b. Electroetching shall be performed using Movipol units or equivalent approved by the procuring activity. The recommended etching solution is the same as that used for electropolishing as specified in 3.2.1.3. The recommended current density is 0.2-0.4 ampere and the recommended etching time is 3 to 4 seconds.

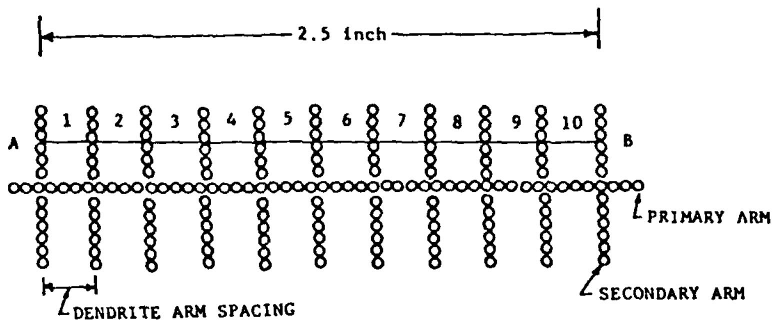

FIGURE 2. SCHEMATIC DIAGRAM OF DENDRITE ARM SPACINGS

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3.3.2.2 Microstructure replication. For the purpose of DAS measurements, the microstructure of the etched location on the casting and test coupons shall be transferred to a plastic replica using the equipment specified in 3.1.3 and standard replicating techniques.

a. The replica may be "shadowed" by vapor deposition to enhance the microstructure contrast.

b. A 100X photomicrograph of the replica showing clearly defined dendrites shall be made using standard techniques and the equipment specified in 3.1.4.

c. The plastic replica and its photomicrographs shall be identified by test location and placed within an envelope that identifies the test casting represented.

d. After completion of the replicating operation, the test area of the casting shall be thoroughly cleaned with acetone and wiped dry with a clean, lint-free cloth to assure that residue and contaminants are removed.

3.3.2.3 DAS measurements. The DAS measurement shall be made by the intercept method which consists of drawing a straight line through the microstructure on the photomicrograph and counting the number of secondary dendrite arm spacings intercepting the line. DAS is calculated according to:

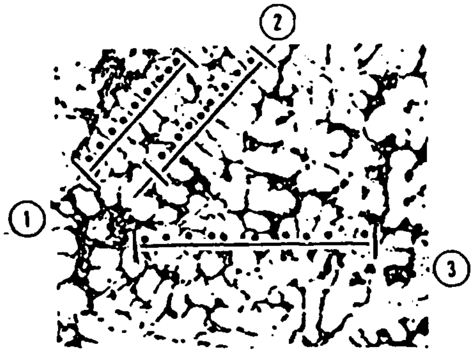
$$\text{DAS, in.} = \frac{\text{Length of intercept line (inches)}}{\text{No. of intercepting secondary arm spacings}} \times \frac{1}{\text{mag.}}$$

3.3.2.3.1 Schematic presentation. A schematic presentation of dendrite pattern magnified 100 times is shown in figure 2. There are 10 dendrite arm spacings intercepting the line AB (2.5 inches long). DAS is calculated as follows:

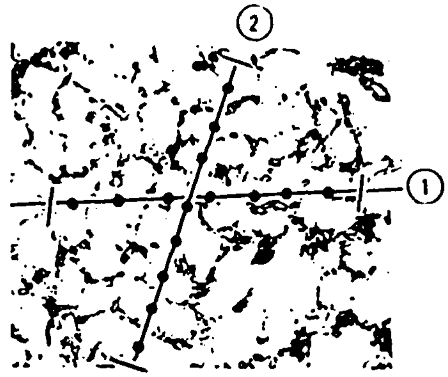
$$\text{DAS, inches} = \frac{2.5}{10} \times \frac{1}{100} = 0.0025 \text{ inch}$$

3.3.2.3.2 Direction of measurements. At least two DAS measurements shall be made at each test location, including tensile specimens. The test area should be carefully scanned and, when possible, the measurements should be taken at angles approaching 90° to each other, but they may be parallel if necessary. Figure 3 shows some typical DAS layouts, measurements, and calculations.

3.3.2.3.3 Calculated averages. The average DAS values shall be reported for each test location and for each area designated on the drawing (i.e., "critical" or "other") when there is more than one test location per area.



A 100X



B 100X

DAS, inch

Location 1

$$DAS = \frac{1 \text{ inch Distance}}{9 \text{ Spacings}} \times \frac{1}{100}$$

DAS = 0.0011 inch

Location 2

$$DAS = \frac{1 \text{ inch Distance}}{8 \text{ Spacings}} \times \frac{1}{100}$$

DAS = 0.0012 inch

Location 3

$$DAS = \frac{1.5 \text{ inch Distance}}{10 \text{ Spacings}} \times \frac{1}{100}$$

DAS = 0.0015 inch

Average of Area

$$DAS = \frac{0.0011 + 0.0012 + 0.0015}{3}$$

DAS = 0.0013 inch

DAS, inch

Location 1

$$DAS = \frac{2 \text{ inch Distance}}{7 \text{ Spacings}} \times \frac{1}{100}$$

DAS = 0.0029 inch

Location 2

$$DAS = \frac{2 \text{ inch Distance}}{8 \text{ Spacings}} \times \frac{1}{100}$$

DAS = 0.0025 inch

Average of Area

$$DAS = \frac{0.0025 + 0.0025}{2}$$

DAS = 0.0027 inch

FIGURE 3. INTERCEPT METHOD OF DETERMINING DENDRITE ARM SPACINGS

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3.3.2.3.4 DAS acceptance criteria. The DAS for each designated area of a production casting for which the drawing requires a specific combination of ultimate strength, yield strength, and elongation (i.e., 50-40-5) shall be equal to or less than the average DAS calculated using all the DAS values obtained for the same area during preproduction evaluation conducted in accordance with M-XXXX (e.g., 50-40-5 - the average DAS $\lesssim$ 0.0010).

3.4 Recommended procedures and operations.

3.4.1 Test procedures.

3.4.1.1 Test location preparation.

3.4.1.1.1 Prereplication surface check. Prior to making a replica of the test location microstructure, it is recommended that preliminary checks of the prepolished, polished, and etched surfaces be made with the hand-held microscope specified in 3.1.5 to determine if the surface has been properly prepared before the next operation is conducted.

3.5 Certification of procedures and personnel. The casting supplier must receive certification of his DAS measurement procedures and personnel prior to the delivery of any casting made in accordance with M-XXXX. Any change in the certified procedures or personnel list will require re-certification. To obtain certification or recertification, the supplier must submit the following information to the procuring activity:

3.5.1 Procedure certification. Submit documented procedures defining specific operations and equipment to be used, and copies of all reports or operation sheets used for recording results of DAS tests as specified in 4.3.

3.5.2 Personnel certification. Submit the names of candidate personnel and a brief resume of their qualifications and capabilities to accurately determine DAS measurements.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibilities. Unless otherwise specified in the contract or purchase order, the casting supplier is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified, the supplier may utilize his own facilities or those of a commercial laboratory acceptable to the procuring activity. The procuring activity has the right to perform any of the inspections set forth in this specification, including the destructive testing of selected production castings, when such inspection is deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Maintenance of materials. The quality of all materials listed in 3.2 shall be periodically monitored to assure that they are of proper quality and consistency such that satisfactory results can be obtained with their use.

4.3 Certification of DAS procedures and personnel. For consideration of procedures and personnel approval, the casting supplier shall document the materials, operations, and steps required to conduct satisfactory DAS measurements for each casting of a different part number made in accordance with MIL-A-XXXX. The document shall include, but not be limited to, the following information derived from the preproduction evaluation:

a. Part number of casting.

b. Laboratory conducting DAS tests.

c. Date testing was conducted.

d. Surface preparation equipment including prepolishing, polishing, etching, and replicating equipment.

e. Materials including abrasives (size of grit), polishing compounds, etchants, type of replicating materials, etc.

f. Type and magnifying power of hand-held microscope.

g. Metallographic equipment -- type, name, and magnification used.

h. Test report, including test locations, replicas, copies of photomicrograph showing DAS intercept lines, data sheets containing DAS calculations and results, with tensile data when required, and names of all personnel conducting procedures qualification DAS measurements.

i. Resumes defining the qualifications of personnel conducting DAS measurements.

j. Signatures of the casting supplier's representative.

4.4 DAS testing instructions. DAS measurements shall be made on all preproduction and production castings as required by M-XXXX in accordance with the procedures and requirements of this specification.

4.5 Test reports. DAS measurements shall be reported on the same form as used to report the results of the tensile tests required by M-XXXX. When tensile tests are required, the results shall be reported with the corresponding DAS results.

4.6 Records. The plastic replicas and at least one legible copy of the corresponding photomicrograph showing the DAS measurements shall be kept on file at the testing facility for a period of six (6) months except as specified in 4.6.1 or as specified in the purchase order.

4.6.1 DAS qualification casting records. A copy of the DAS test results, including the photomicrographs, from each preproduction qualification casting shall be forwarded to the procuring activity.

4.6.2 Production casting records. One copy of each DAS and tensile test report shall be forwarded directly to the procuring activity. In cases where a laboratory other than that of the casting supplier conducts the tests, a minimum of two (2) copies of the test reports shall be forwarded to the casting supplier, one of which shall be forwarded to the procuring activity with the production castings.

5. PREPARATION FOR DELIVERY. This section is not applicable to this specification.

6. NOTES

6.1 Intended use. Dendrite arm spacing (DAS) measurements are intended for use as a nondestructive testing method to aid in determining that the strength and ductility of structural A357 castings made in accordance with M-XXXX meet the requirements of that specification and the Engineering drawing.

6.2 Definitions. The following terms and their definitions as applied to this specification are:

a. Dendrite arm spacing (DAS). The distance from the center of one secondary arm to the center of the adjacent secondary arm of a dendrite.

b. Tensile coupon. A cast-on appendage or a selected area of a casting that is designated to be destructively tested in tension.

c. Tensile specimen. The final configuration that is excised or otherwise prepared from the tensile coupon for testing.

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